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LUNAR SURFACE MOBILITY SYSTEMS COMPARISON AND EVOLUTION (MOBEV)

FINAL REPORT

VOLUME II
BOOK 7
EVOLUTION METHODOLOGY USER'S MANUAL

BSR 1428

NOVEMBER 1966

THE Bendix CORPORATION Aerospace Systems Division

FINAL REPORT

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LUNAR SURFACE MOBILITY SYSTEMS COMPARISON AND EVOLUTION (MOBEV)

FINAL REPORT

VOLUME II

BOOK 7

EVOLUTION METHODOLOGY USER'S MANUAL

BSR 1428

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER,
HUNTSVILLE, ALABAMA
UNDER CONTRACT NO. NAS8 - 20334

Approved by: C. J. Weatherred
C. J. Weatherred, Director
Lunar Vehicle Programs

NOVEMBER 1966

THE Bendix CORPORATION **Aerospace Systems Division**

FOREWORD

This document presents the results of the Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV) conducted for the National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama, under Contract NAS8-20334. The Bendix team responsible for the MOBEV Study includes Bendix Systems Division of The Bendix Corporation, Bell Aerosystems Company, and Lockheed Missiles and Space Company. Bendix, in addition to overall program management and system integration, has been responsible for LRV Systems, Mission Studies, and the MOBEV Methodology. Bell has been responsible for the Flying Vehicle Systems; Lockheed has been responsible for the LRV Human Factors, Environmental Control, Life Support, and Cabin Structures.

The Study was performed by personnel of the Lunar Vehicle Program Directorate of Bendix Systems Division, The Bendix Corporation, under the direction of Mr. C. J. Weatherred, Program Director; Mr. R. E. Wong, Engineering Manager; and Mr. C. J. Muscolino, Project Manager, MOBEV. The NASA Technical Supervisor for the contract was Mr. Richard Love, R-P&VE-AA, Marshall Space Flight Center.

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ABBREVIATIONS AND VEHICLE NOMENCLATURE

LM	-	Apollo Lunar Module
CM	-	Apollo Command Module
CAN	-	Multimission Module
LM-Shelter	-	Two-Man Lunar Shelter derived from Apollo Lunar Module
LM-Truck (LM-T)	-	Logistics Delivery System derived from Apollo Lunar Module descent stage
MOLEM	-	Lunar Surface Mobility System derived from LM
MOCOM	-	Lunar Surface Mobility System derived from CM
MOCAN	-	Lunar Surface Mobility System derived from CAN
ECS	-	Environmental Control System
RTG	-	Radiosotope Thermoelectric Generator
ELMS	-	Engineering Lunar Model Surface
PLSS	-	Portable Life Support System
LIOH	-	Lithium Hydroxide
EVA	-	Extra Vehicular Activity
O_2	-	Oxygen
H_2	-	Hydrogen
EPS	-	Electrical Power System
SNAP	-	Space Nuclear Auxilary Power System
TDM	-	Traction Drive Motor
SDM	-	Steering Drive Mechanism
IMU	-	Inertial Measurement Unit
AOT	-	Alignment Optical Telescope
ALSS	-	Apollo Logistics Support Systems
P&W	-	Pratt and Whitney
MTA	-	Mobility Test Article
SRC	-	Specific Reactant Consumption
LSSM	-	Local Scientific Survey Module
MSFN	-	Manned Space Flight Network
KSC	-	Kennedy Space Center
MOLAB	-	Mobile Laboratory
MCC	-	Mission Control Center
A/L	-	Dimension from rear wheels to CG over total length
i_{opt}	-	Point of Slip at which maximum thrust is developed
AES	-	Apollo Extension Systems
LESA	-	Lunar Exploration Systems for Apollo
AAP	-	Apollo Applications Program

The following nomenclature is used throughout the report and was adopted to facilitate recognition of the large number of vehicles and missions considered.

ROVING VEHICLES

1. First (letter) (R) defines vehicle as Rover.

2. Second (number) (0 through 3) defines vehicle crew size.

3. Third (letter) (A through D) defines specific mission of vehicle.

4. Fourth (letter) (E or B) defines vehicle as being Exploration or Base Support vehicle.

Example: R1BE (rover—one man—vehicle B mission—exploration vehicle)

FLYING VEHICLES

1. First (letter) (F) defines vehicle as Flyer.

2. Second (number) (0 through 3) defines vehicle crew size.

3. Third (letter) (A through E) defines specific mission of vehicle.

Example: F1B (flyer—one man—vehicle B mission)

CSM	- Apollo Command and Service Module
G&N	- Guidance and Navigation
AES-MLS	- AES Manned Lunar Surface
ALSEP	- Apollo Lunar Surface Experiments Package
LFV	- Lunar Flying Vehicle
MFS	- Manned Flying System
MIMOSA	- Mission Modes and Systems Analysis for Lunar Exploration
SLRV	- Surveyor Lunar Roving Vehicle
DPV	- Design Point Vehicles
LLV	- Lunar Logistics Vehicle
ESS	- Emplaced Scientific Station

SECTION 1

INTRODUCTION

The Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV), Contract NAS8-20334, was initiated in February 1966. The relationship between the Evolution Methodology and the MOBEV design and resources development efforts is shown in Figure 1-1.

1.1 METHODOLOGY OBJECTIVE

The methodology, as defined in this study, is the method by which a planner may select, from many possible combinations of vehicles, a preferred combination (evolution) for development and application in the 1970-1980 era. A spectrum of vehicles designed to cover all reasonable mobility needs in this era was developed as part of the MOBEV Study. These vehicles are summarized in Section 1.2. Cost and schedule data for each vehicle, with and without prior development considered, has also been developed. The methodology refers, then, to the process through which a planner selects a preferred evolution to accomplish a given exploration program. This selection will clearly be based heavily on the costs involved.

The Methodology Computer Program described in this book is a tool developed to handle the most significant of the large amount of vehicular performance and cost data generated under other MOBEV efforts. The planner can thus get quick, convenient, and sufficiently accurate relative cost evaluations of complex exploration programs without searching through the detailed data contained in the accompanying Design Point Vehicle Data Book and other books of this report, and without detailed knowledge of the numerous assumptions and technical details involved in vehicular design, mission analysis, and cost estimating.

1.2 DESIGN POINT VEHICLES

Thirty-three vehicles, here after termed Design Point Vehicles (DPV), were selected as comprising a reasonable mobility spectrum for the 1970-1980 era of lunar surface exploration. These vehicles include both Flyers

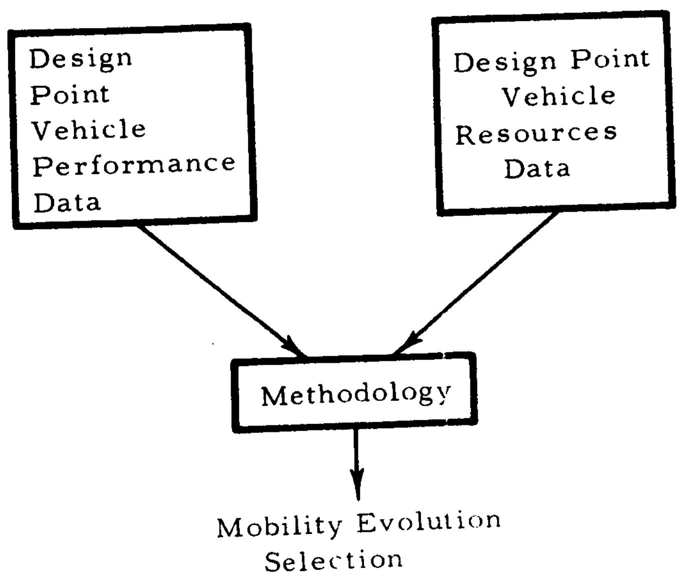
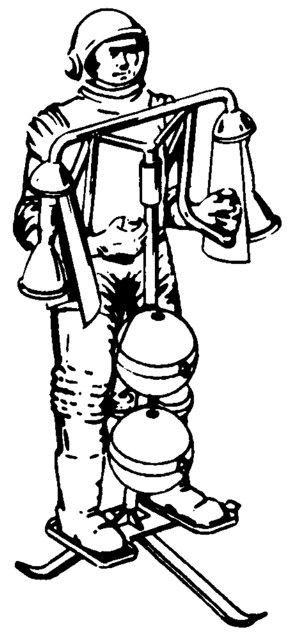
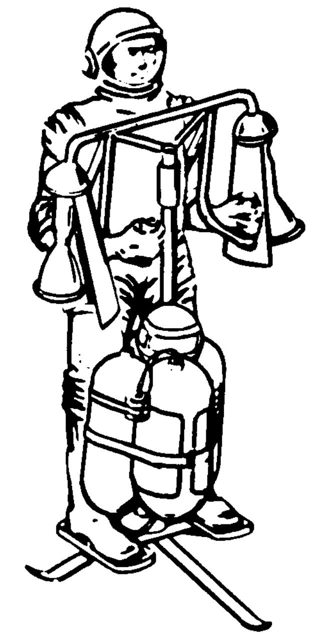


Figure 1-1 Relationship of Methodology to Other MOBEV Efforts

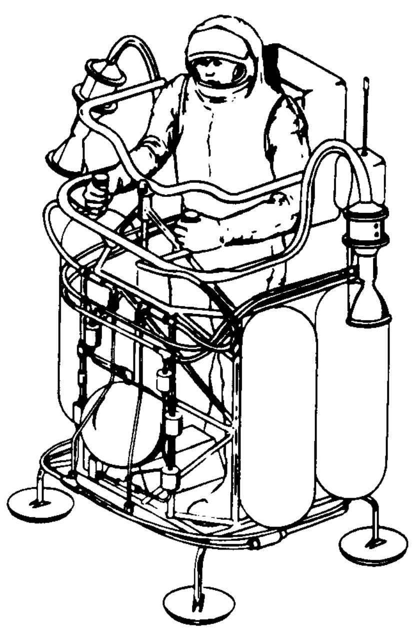
and Surface Rovers. The Flyers, in turn, include both those employed for surface exploration or rescue and those capable of returning astronauts and payload from the lunar surface to lunar orbit. The Rovers include vehicles for surface exploration or rescue and also base support operations. Figures 1-2 through 1-5 present the DPVs in convenient form with a minimum of description. Each vehicle carries a code name (e.g., R0AE) as well as a number. The vehicle number is used for identification in the computer program. These vehicles, then, comprise the current library of available vehicles within the computer program. The computer program is designed to handle up to 50 vehicles.



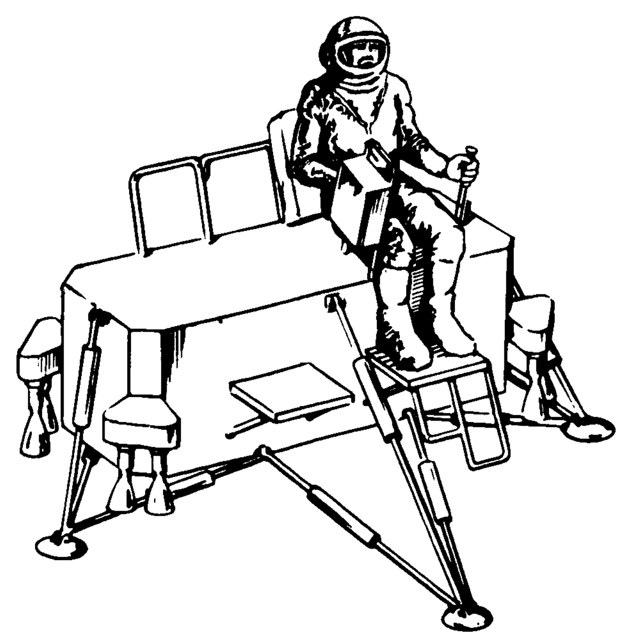
Vehicle No. 1
Code Name F-1-A
Fueled Mass 64.1 kg
Crew Size 1



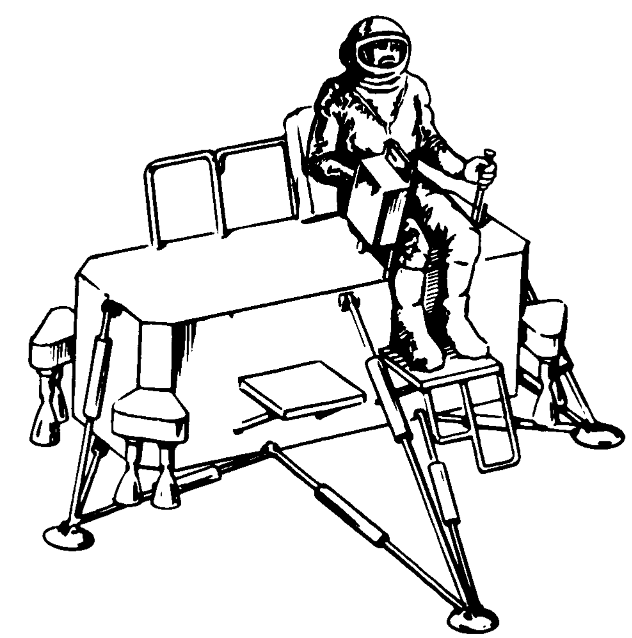
Vehicle No. 2
Code Name F-1-B
Fueled Mass 82.0 kg
Crew Size 1



Vehicle No. 3
Code Name F-1-C
Fueled Mass 309.9 kg
Crew Size 1

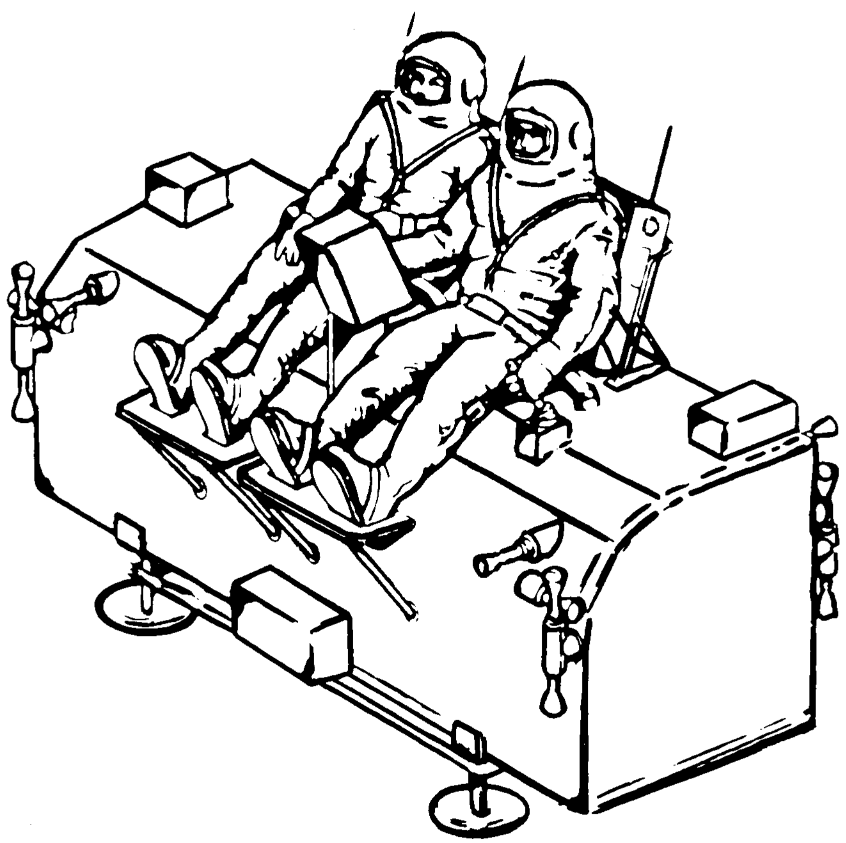


Vehicle No's	4	5	6	7
Code Name	F-2-A	F-2-B	F-2-C	F-2-D
Fueled Mass (kg)	287.9	391.8	530.5	788.3
Crew Size	2	2	2	2

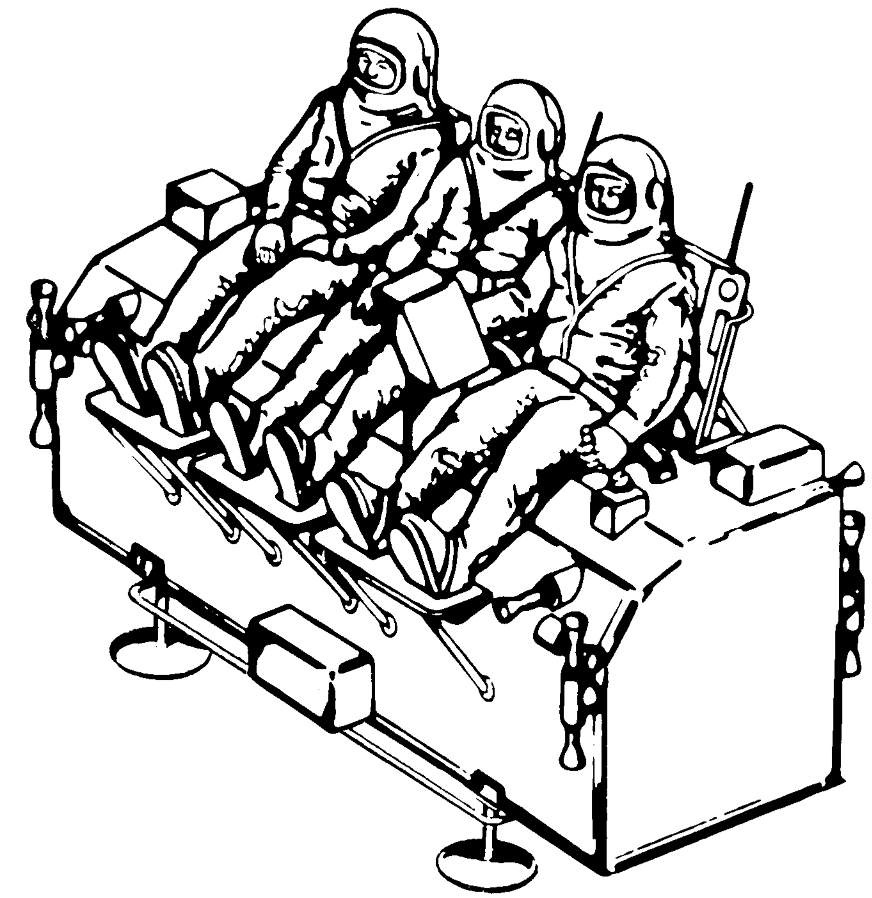


Vehicle No's	9	10	11	12
Code Name	F-3-A	F-3-B	F-3-C	F-3-D
Fueled Mass (kg)	529.1	1074.5	2066.5	4209.4
Crew Size	3	3	3	3

Figure 1-2 Flyers—Exploration or Rescue

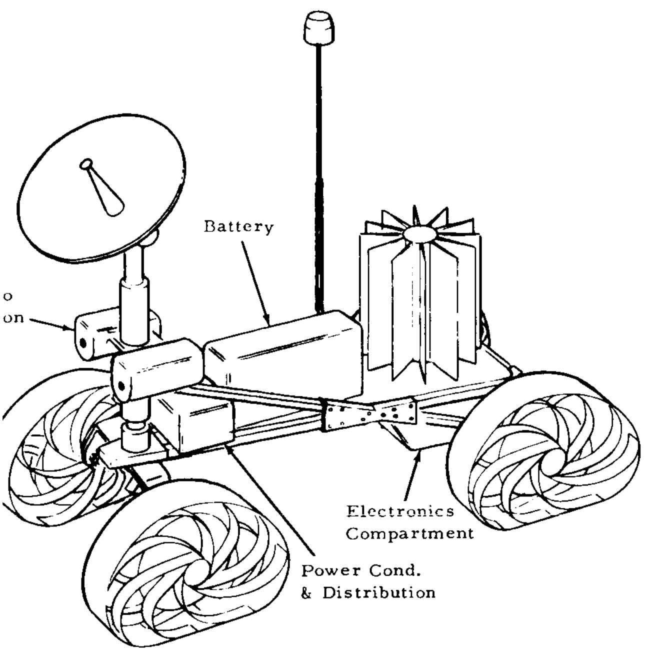


Vehicle No. 8
Code Name F-2-E
Fueled Mass 1106. 5 kg
Crew Size 2

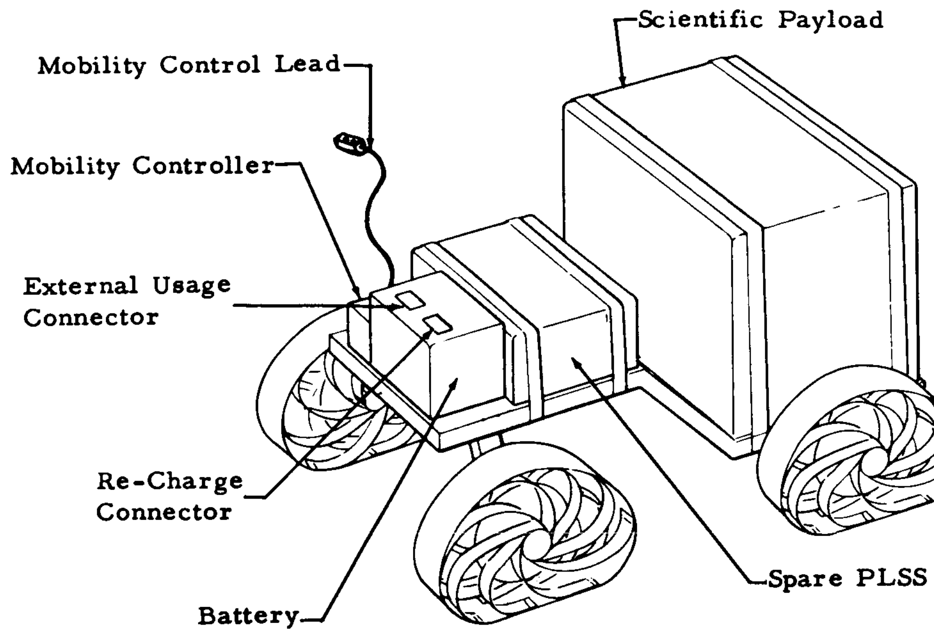


Vehicle No. 13
Code Name F-3-E
Fueled Mass 1476. 5 kg
Crew Size 3

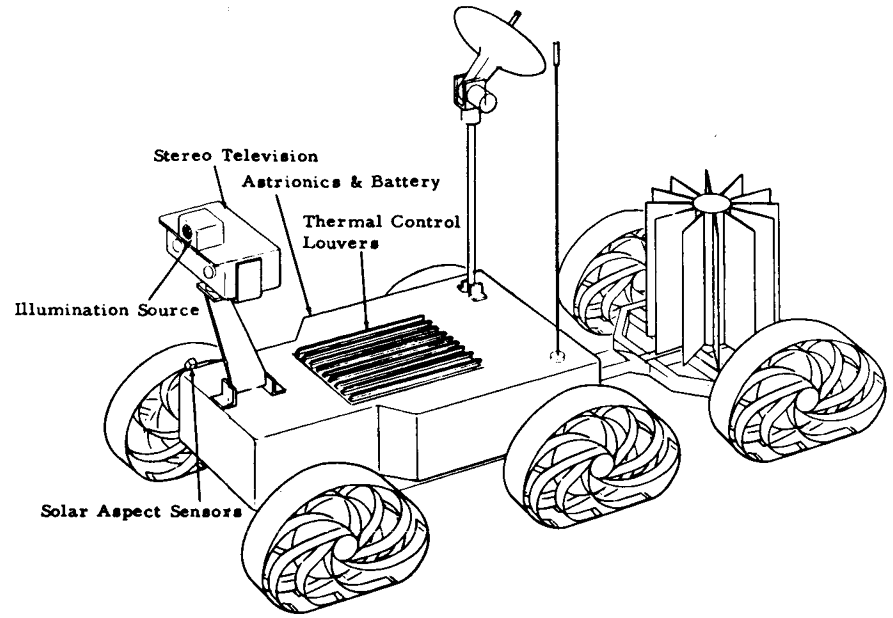
Figure 1-3 Flyers—Return-to-Orbit



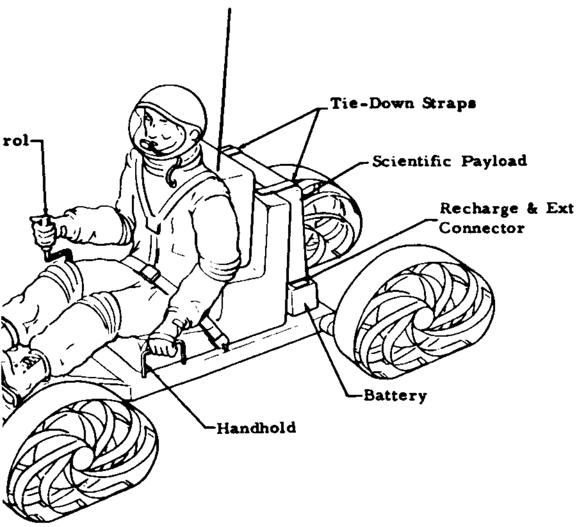
Vehicle No. 14
Code Name R0AE
Fueled Mass 62.0 kg
Crew Size 0



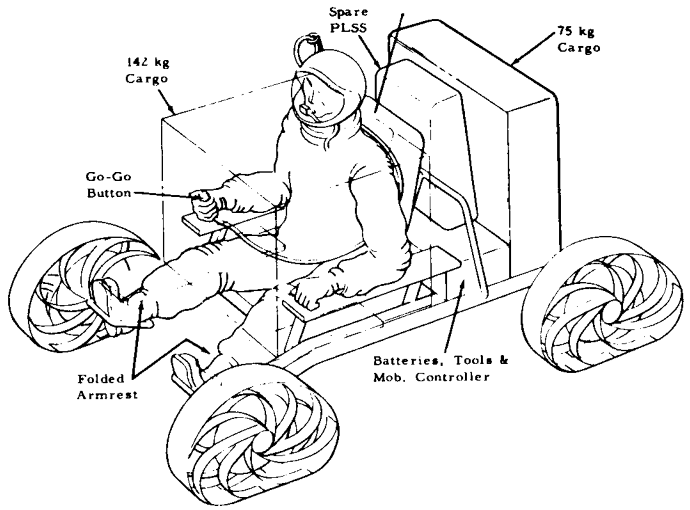
Vehicle No. 15
Code Name R0BE
Fueled Mass 170.0 kg
Crew Size 0



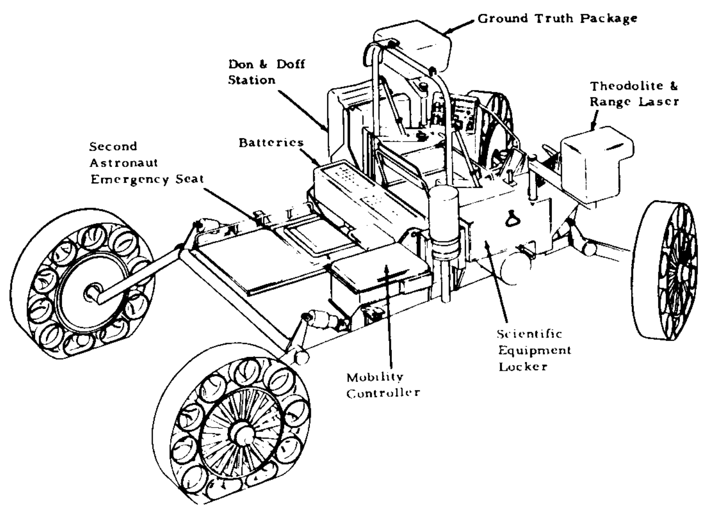
Vehicle No. 16
Code Name R0CE
Fueled Mass 148.0 kg
Crew Size 0



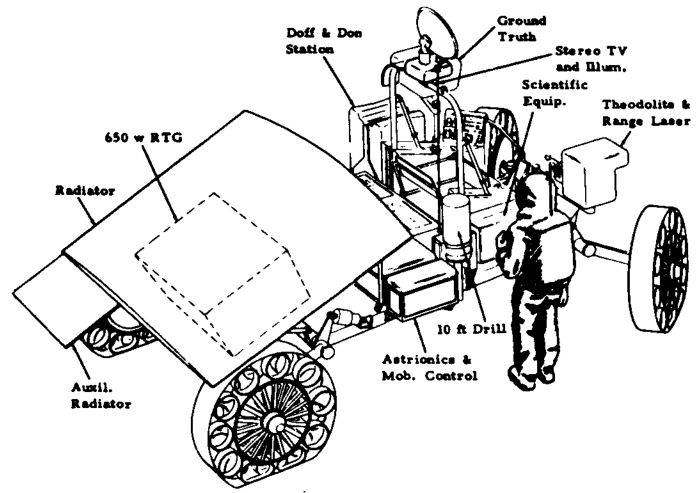
Vehicle No. 17
Code Name R1AE
Fueled Mass 288.0 kg
Crew Size 1



Vehicle No. 18
Code Name R1A(1)E
Fueled Mass 378.9 kg
Crew Size 1

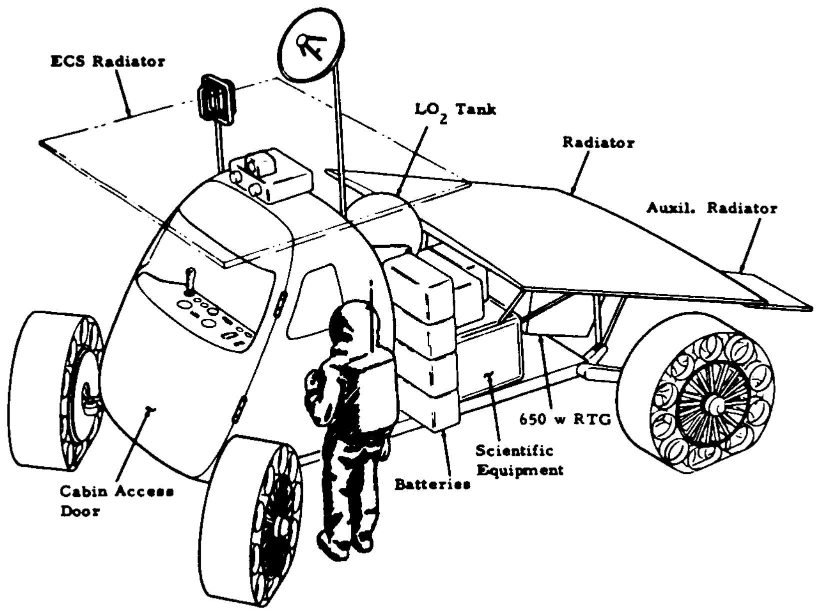


Vehicle No. 19
Code Name R1BE
Fueled Mass 867.1 kg
Crew Size 1

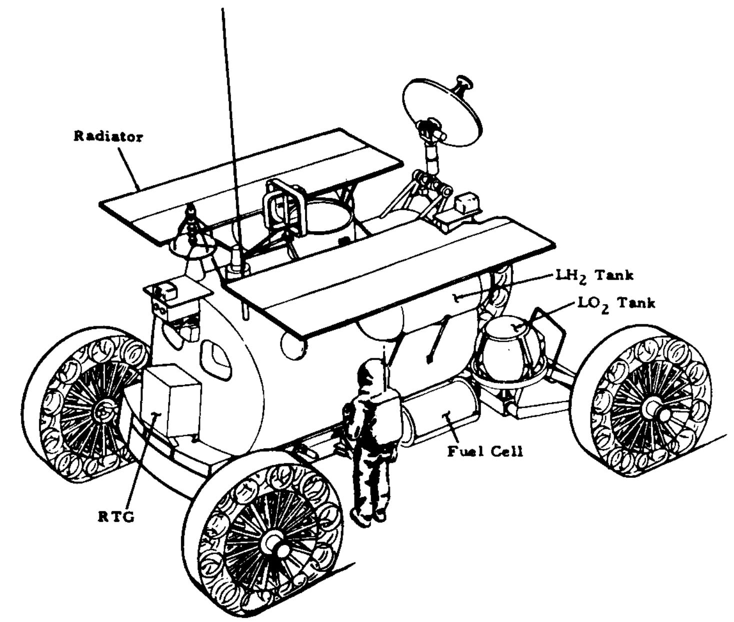


Vehicle No. 20
Code Name R1B(1)E
Fueled Mass 1270.0 kg
Crew Size 1

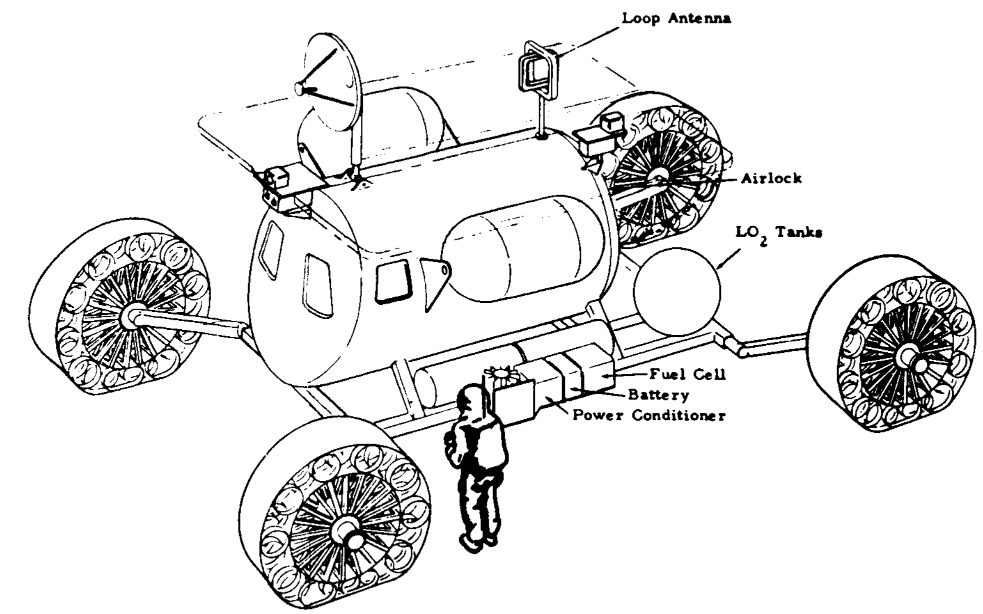
Figure 1-4 Rovers—Exploration or Rescue
(page 1 of 2)



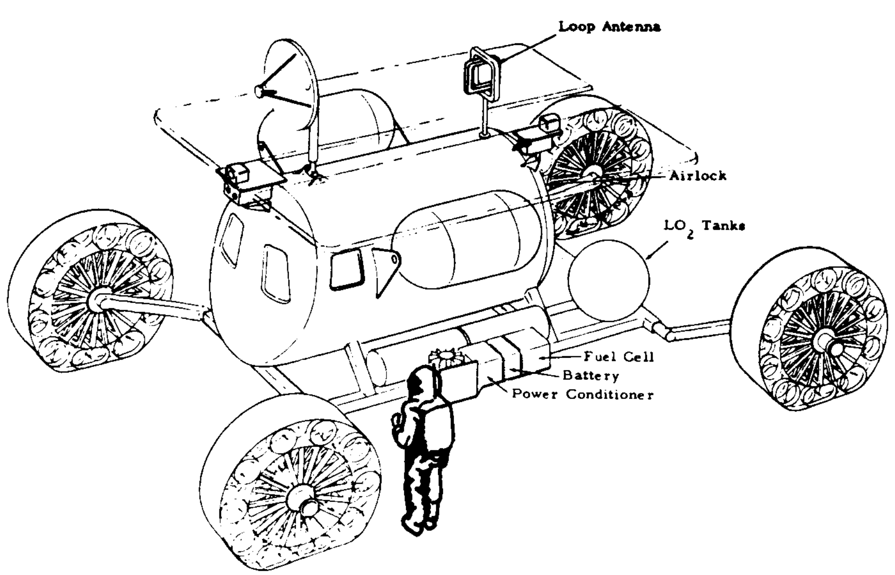
Vehicle No. 21
Code Name R1DE
Fueled Mass 2022.0 kg
Crew Size 1



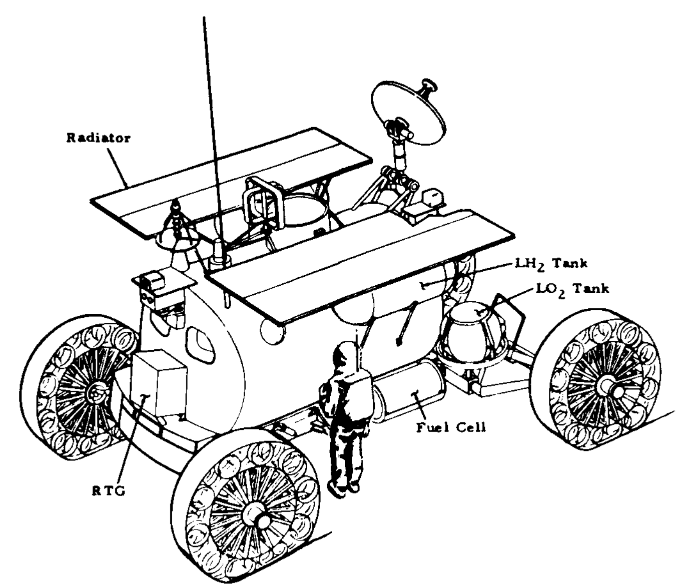
Vehicle No. 22
Code Name R2C(1)E
Fueled Mass 3390.0 kg
Crew Size 2



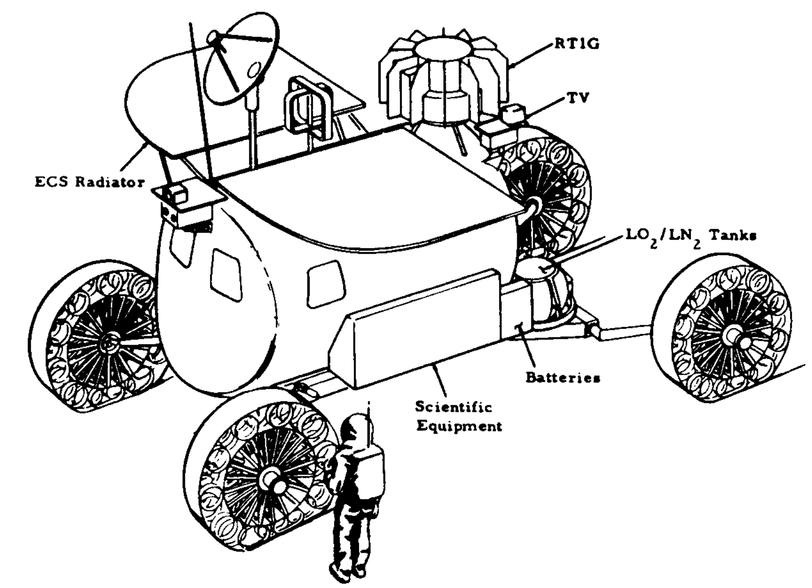
Vehicle No. 23
Code Name R3AE
Fueled Mass 5522.0 kg
Crew Size 3



Vehicle No. 24
Code Name R3BE
Fueled Mass 7655.0 kg
Crew Size 3



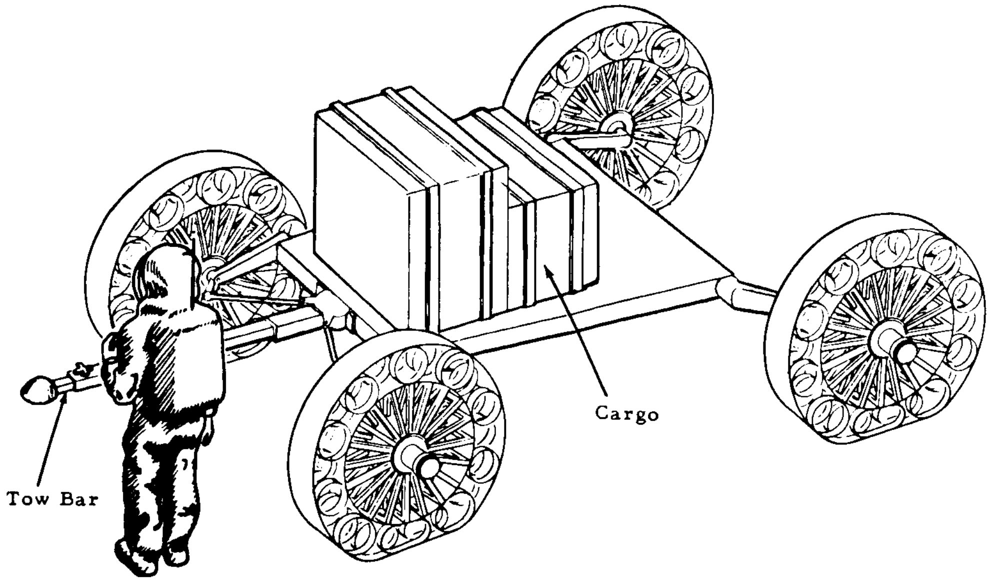
Vehicle No. 25
Code Name R3CE
Fueled Mass 3893.0 kg
Crew Size 3



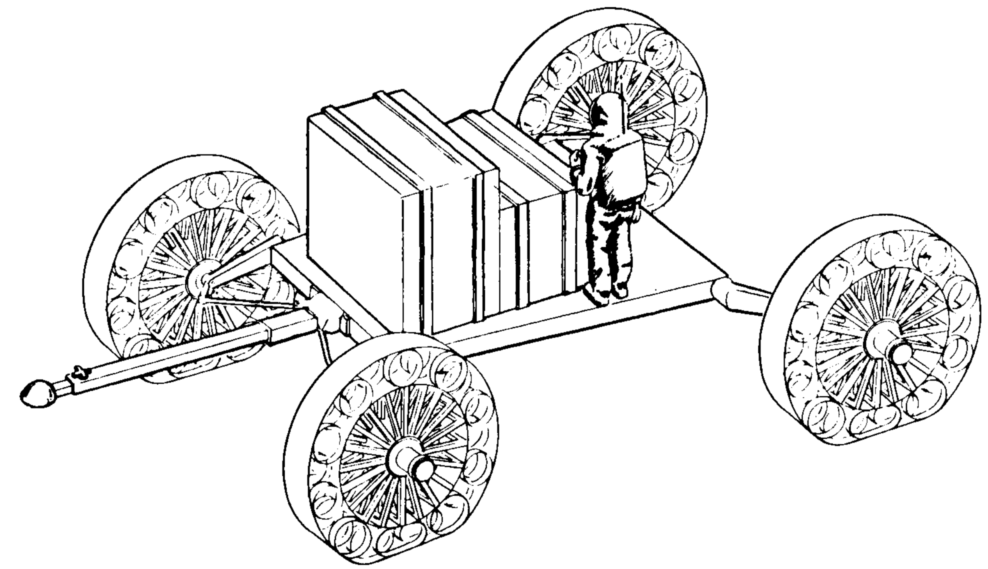
Vehicle No. 26
Code Name R3DE
Fueled Mass 8446.0 kg
Crew Size 3

Figure 1-4 Rovers—Exploration or Rescue
(page 2 of 2)

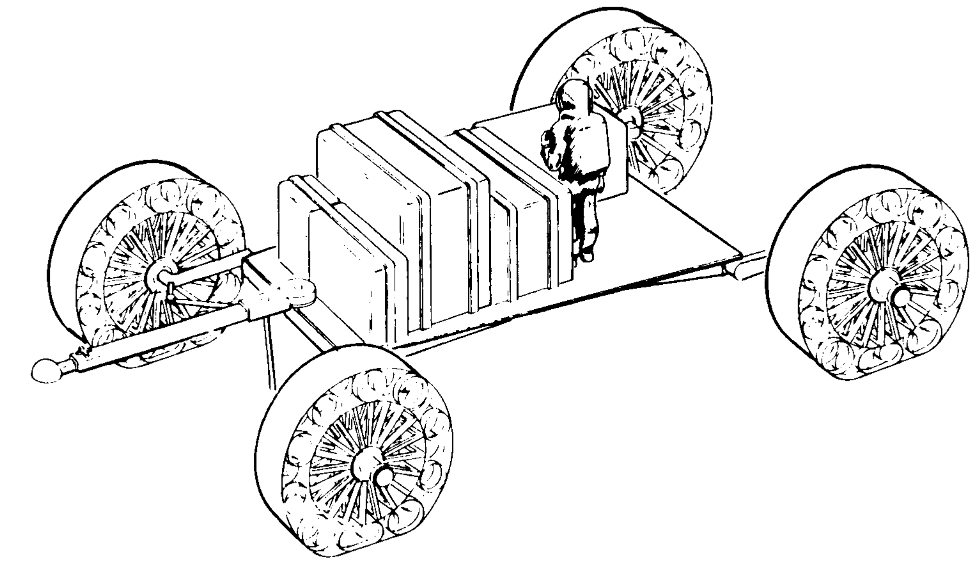
TRAILERS



Vehicle No. 27
Code Name R0AB
Vehicle Mass 285.0 kg

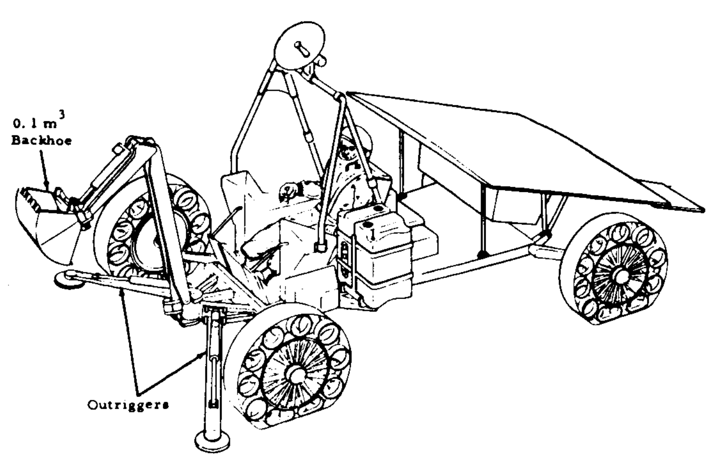


Vehicle No. 28
Code Name R0BB
Vehicle Mass 565.0 kg

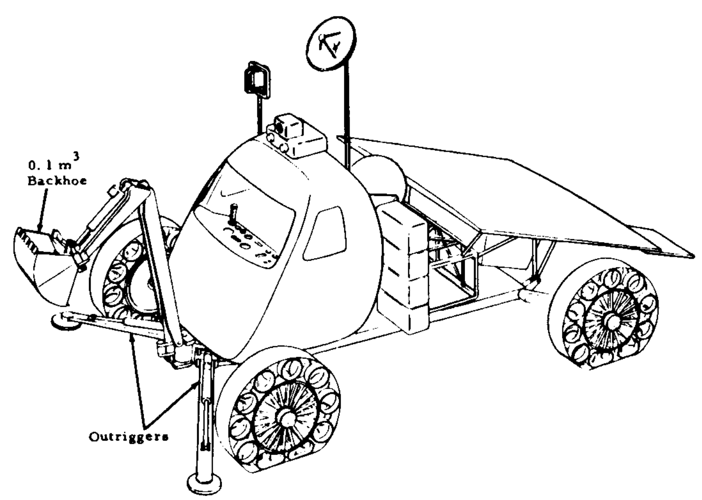


Vehicle No. 29
Code Name R0CB
Vehicle Mass 1205.0 kg

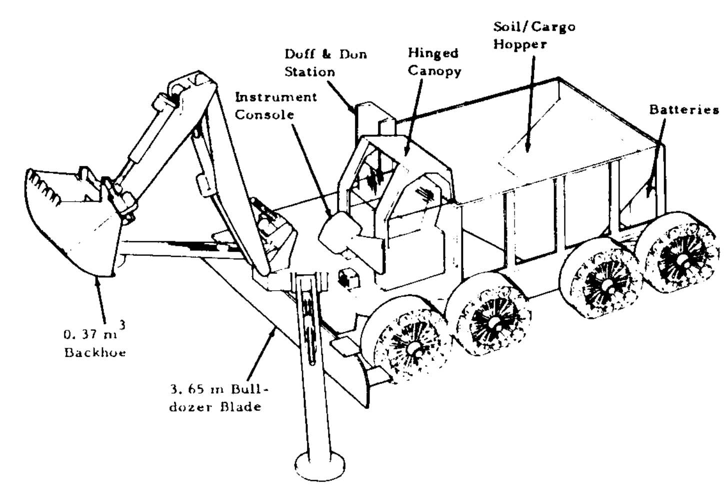
PRIME MOVERS



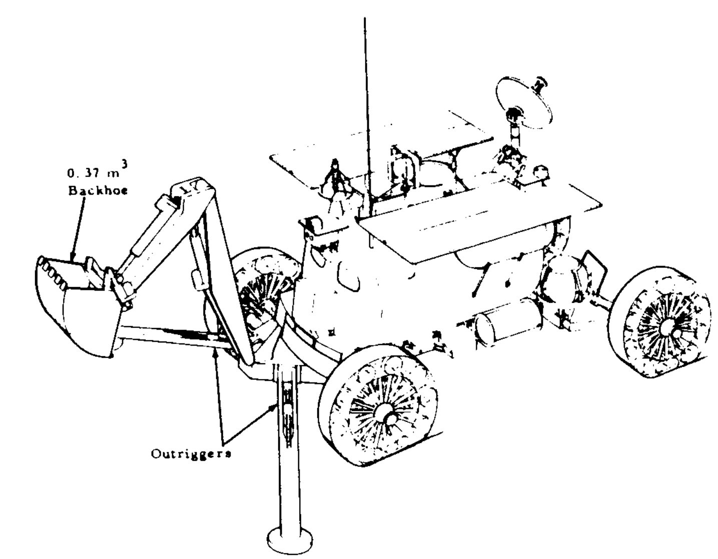
Vehicle No. 30
Code Name R1AB
Vehicle Mass 798.0 kg



Vehicle No. 31
Code Name R1BB
Vehicle Mass 1604.0 kg



Vehicle No. 32
Code Name R1CB
Vehicle Mass 2701.0 kg



Vehicle No. 33
Code Name R2BB
Vehicle Mass 2800.0 kg

Figure 1-5 Base Support Vehicles

1.3 SUMMARY

This book contains a detailed explanation of the use of the MOBEV Evolution Methodology Computer Program. Details of its development are given in Volume II, Book 6 of the Final Report.

A description of the overall program is presented first, covering the logic embodied in the program. Input requirements and outputs available are then discussed in detail. Next applications of the computer program in the planning of lunar surface exploration are covered, both from the large-scale viewpoint involving exploration programs comprised of up to 20 missions, and from a smaller, more restricted viewpoint involving, for example, vehicle/mission trade-offs.

Appendix A lists the symbols used in the logic flow charts, and Appendix B defines all terms. The detailed flow charts appear as Appendix C. Technical data used in the program, pertaining to the Design Point Vehicles, are documented in Appendix D. Appendix E contains the associated cost data.

Figure 1-6 summarizes the contents of this book.

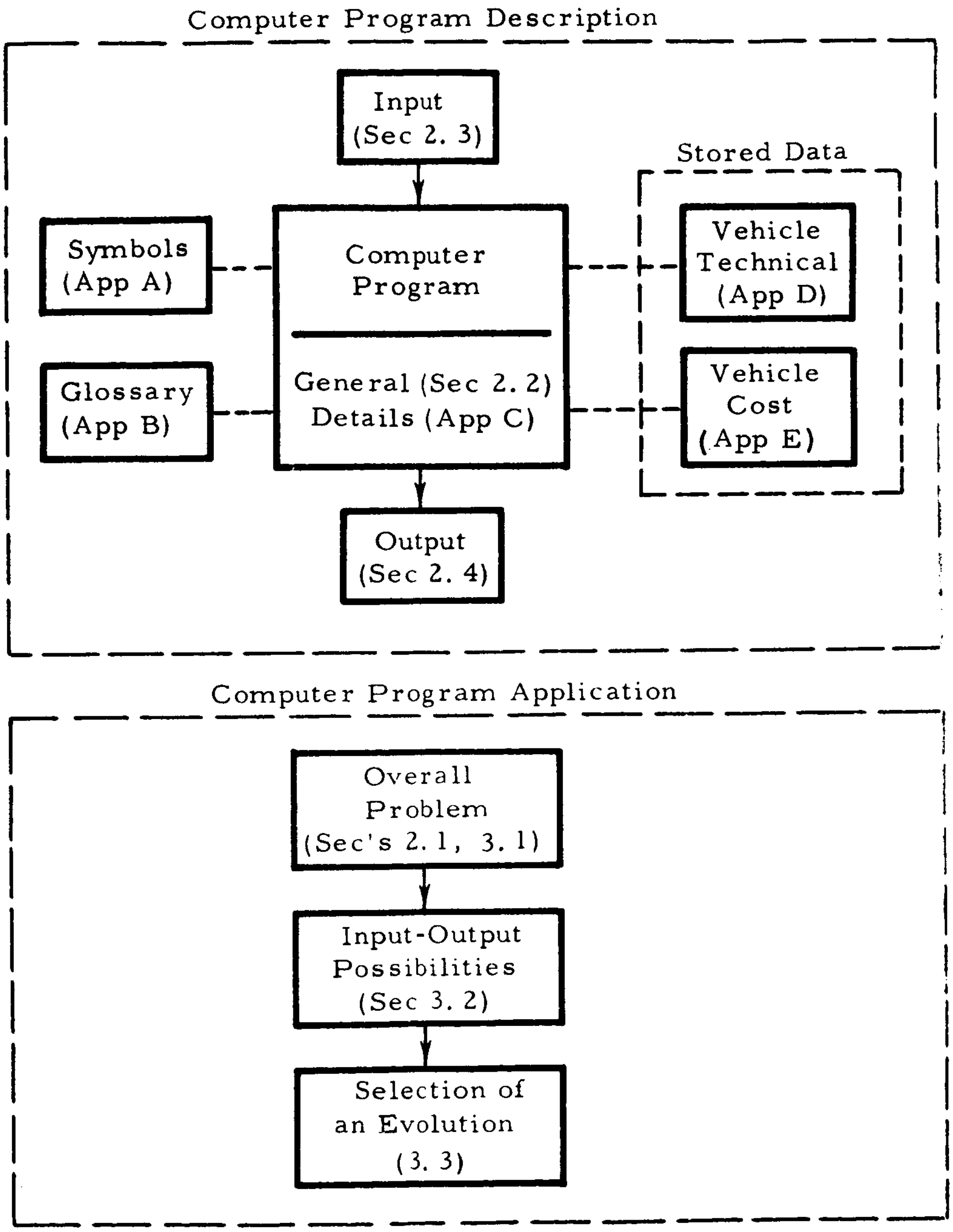


Figure 1-6 Summary of Methodology Computer Program User's Manual

SECTION 2

COMPUTER PROGRAM DESCRIPTION

Although the main purpose of this section is to describe the gross aspects of the computer program, it is necessary first to discuss the problem which this tool is designed to explore. Section 2.1 first defines the problem facing the planner of lunar surface mobility systems, and Section 2.2 through 2.4 describe the overall program, the input requirements, and outputs available in that order.

2.1 PROBLEM DEFINITION

The goals for the exploration of the lunar surface and its environment, arising chiefly from the scientific community, may be translated into any number of surface exploration missions to be carried out with the aid of surface mobility systems. Figure2-1 indicates this translation. As the goals change because new information about the lunar surface becomes available, or because of funding constraints, political environments, etc., the missions themselves will too change. Thus, there exist at any one time in this era many preferred sets of missions depending upon the sources polled. For a given mission, there are a large number of mobility concepts adequate to perform the mission. For a given set of missions, then, the number of possible acceptable sets of mobility concepts becomes exceedingly large. If one attempts to select a preferred set of mobility concepts which is defensible both on the basis of satisfying a preferred set of missions and also as representing a cogent selection in terms of cost, the problem of selection is difficult. Again, reference to Figure 2-1 shows the relationships (1) between vehicles and the missions performed, and (2) among vehicle development schedules, and costs. A thorough appreciation of these relationships is fundamental to the choice of a preferred set of vehicles, or as the term is used here, a vehicle evolution.

Figure 2-2 presents the problem in more specific terms. A typical lunar surface exploration program involving eight missions in the 1970s has been assumed. To accomplish the scientific tasks involved in these missions, the mobility requirements are as listed.

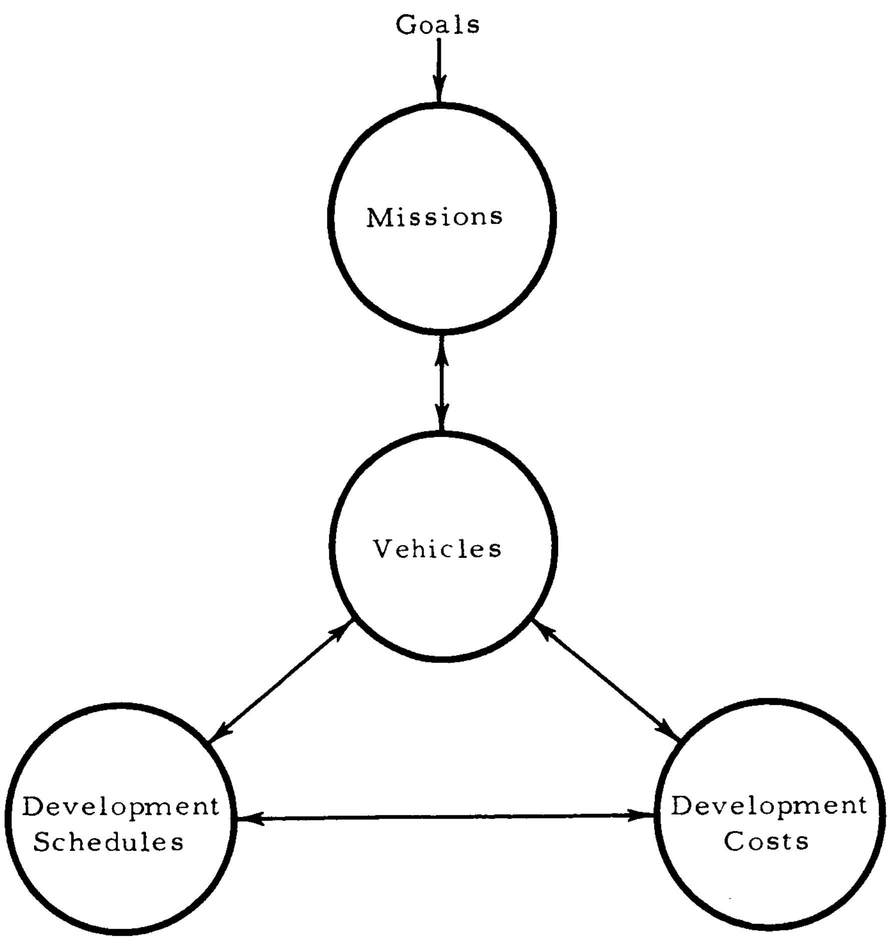


Figure 2-1 Problem Definition

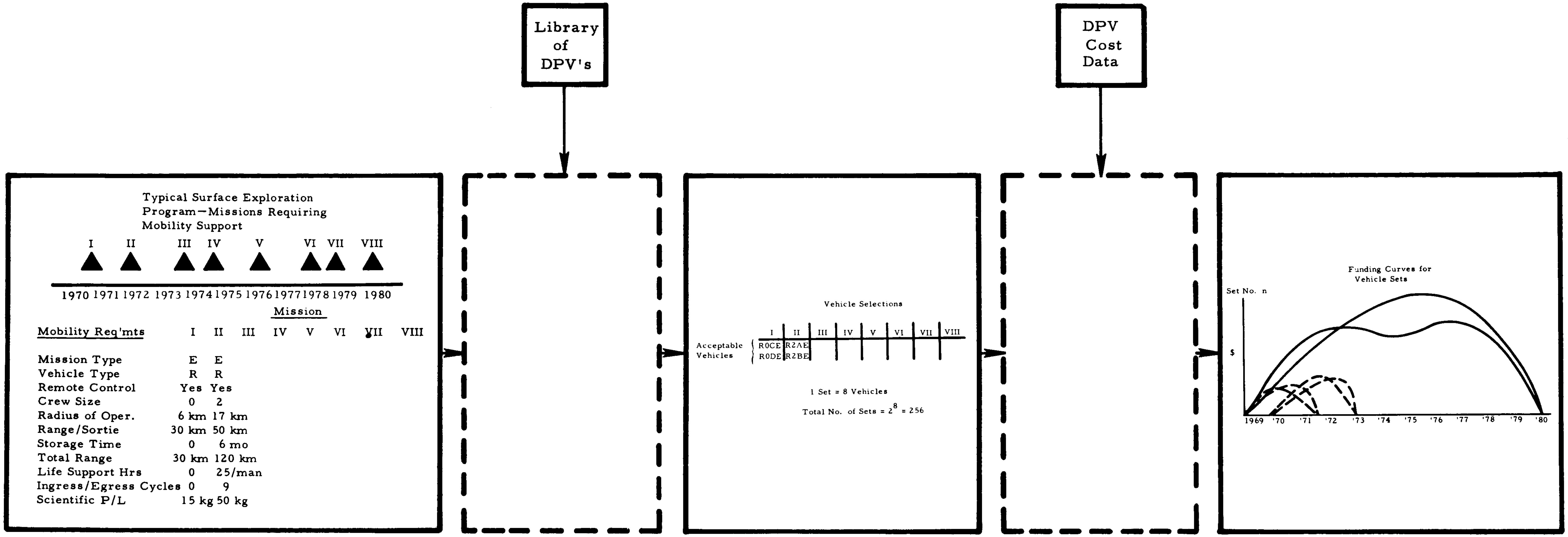


Figure 2-2 Role of the Methodology Cumputer Program

Having available a number of feasible mobility concepts, the planner must then select all vehicles which can perform these missions. This selection, when viewed from the total program standpoint, rapidly gives rise to a large number of possible combinations or sets of vehicles to be considered. In this instance, two acceptable vehicles for each of eight missions would result in 256 vehicle combinations which would satisfy the total program.

With adequate cost data at his disposal, the planner then must consider the cost implications of each of the 256 sets - an extremely time-consuming task.

The Methodology Computer Program is designed to handle the two functions shown by dotted lines in Figure 2-2.

1. Selection of vehicles to perform given missions

2. Providing cost information on sets of vehicles tied to these missions.

In the first step, acceptable vehicles (DPVs) are selected from the 33 vehicles pictured in Figures 1-2 to 1-5. In the second step, the cost data generated for these vehicles are applied to the selected vehicle sets.

2.2 GENERAL PROGRAM STRUCTURE

Figure 2-3 shows the two basic types of problems handled by the program:

1. Vehicle costing

2. Vehicle selection plus costing.

In the normal use of the program, it is expected that the planner would first run the latter problem type, in which missions would be specified, vehicles selected which could perform the missions (from the 33 DPVs in the vehicle library), and finally cost data generated on the vehicles selected. The second stage would then be further runs in the first category, in which those vehicles satisfying mission requirements would be inputed for further cost data.

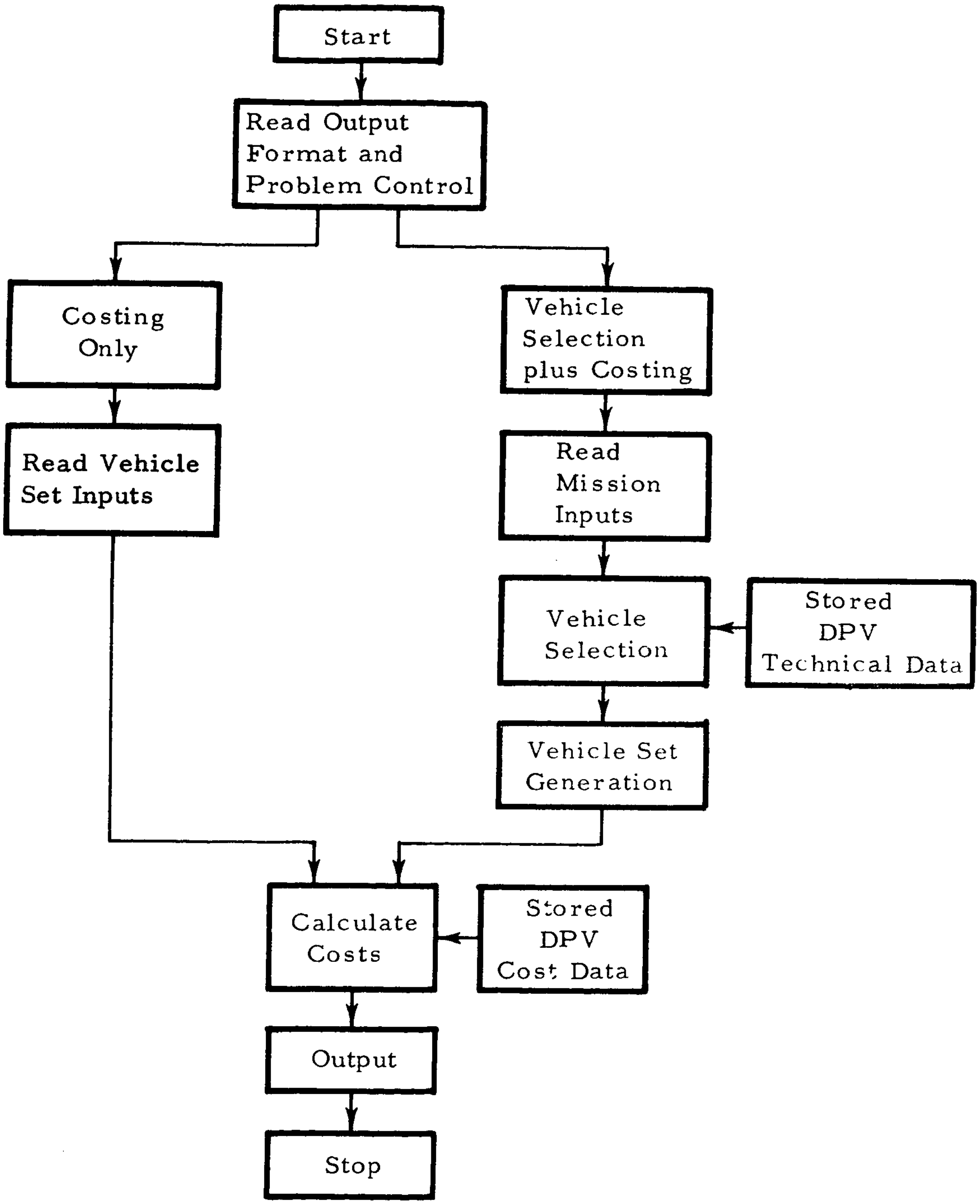


Figure 2-3 General Structure of the Computer Program

Figure 2-4 is similar to Figure 2-3 but shows a little more detail. This figure is repeated as the first figure (overall logic) in Appendix C. The left and right sides of Figures 2-4 and 2-3 correspond in that vehicle costing only is done by moving down the left side, while vehicle selection plus costing is done on the right.

A brief synopsis of each of the dashed blocks of Figure 2-4 will aid in understanding the overall logic. All dashed portions are covered in more detail in Appendix C.

2.2.1 Vehicle Tests

In this block, the performance of the vehicles called for in the blocks above is tailored to the requirements of the missions inputed. More specifically, each vehicle is represented by an amount of fixed mass plus an expendable allotment. The fixed, or unfueled mass, excludes payload, crew, life support, liquid fuels, batteries for mobility, and tankage and packaging factors associated with fuels and batteries. The expendable allotment is the difference between the design operational mass and the unfueled mass and includes all of the above items. The amounts of mass required of a vehicle for mobility, life support, and payload are tabulated for each mission. If a vehicle has a sufficient allotment available to perform a mission, it is accepted: otherwise, it is rejected. Immediately following vehicle tests, Output I may be called for in which the acceptable vehicles and details of their mass utilization are printed. Thus, the planner can determine how much of the expendable allotment is required for a mission, i.e., with what margin the vehicle can perform the mission.

2.2.2 Vehicle Set Generation

Following vehicle tests, there is available a list of acceptable vehicles for each mission. This block then generates all possible combinations of acceptable vehicles, each combination being called a set or evolution. A series of eight missions with two acceptable vehicles per mission would result in 2^8 or 256 sets.

2.2.3 Schedule/Total Cost of Set

In this subroutine, one set of vehicles at a time is first scheduled, (i.e., development start date is set for each vehicle) and then total costs generated. Total costs are generated considering deviations of the required schedule from a nominal schedule, as well as cost savings by reason of prior vehicular developments.

After this subroutine is completed, the sets are arranged in order of increasing cost as seen in Figure 2-4. At this point, the total costs may be printed:

1. Output II if the problem is one of costing only (left side)

2. Output IV if the problem is one of vehicle selection plus costing (right side).

2.2.4 Cost Spreading

If desired by the planner, the total costs derived in schedule/total cost may be spread by half-years over the development schedule established for each vehicle. These spread costs will then be printed by half-years both in total for all vehicles in a set (total exploration program costs) and on each individual vehicle within each set.

Again this output is labeled differently depending upon the type of problem being run:

1. Output III if the problem is one of costing only (left side)

2. Output IV if the problem is one of vehicle selection plus costing (right side).

2.3 INPUT

Because the amount of use which a computer program receives is often inversely proportional to the energy and time required for input preparation, the goal in designing the input for this program was simplicity - to make it as simple and easy as possible to make runs. The input form chosen was a questionnaire consisting partly of fill-in type questions and partly multiple-choice types. The answers to the questionnaire are entered on a prepared answer sheet which can be keypunched directly. Both questionnaire and answer sheet are patterned closely after a form suggested by Ginsberg et al.[1] Two questionnaires have been prepared which correspond to the two major problem types to be run:

---

[1] "Programming by Questionnaire", Allen S. Ginsberg, Harry M. Markowitz, Paula Oldfather, Rand Memo RM-4460-R, April 1965.

1. Costing only (Questionnaire A)

2. Vehicle selection plus costing (Questionnaire G).

Section 2. 3. 1 presents the questionnaires for the problem of the first type, while Section 2. 3. 2 covers the second type.

2. 3. 1 Costing Only

The questionnaire to be filled out by the planner for a problem involving costing only, appears on the following pages. The questionnaire is followed immediately by its prepared answer sheet. (Figures 2-5 and 2-6). Following the answer sheet is a logic tree of the questionnaire (Figure 2-7) which may help in summarizing the content of the questionnaire itself.

In using the questionnaire, the planner merely follows instructions through the questionnaire entering all answers on the prepared sheet. All entries on the answer sheet must be right justified. When a selection is to be made among alternatives, a selection is made by entering a one (1) in the appropriate column of the answer sheet.

The answer sheet is the only input required of the planner. Comments on the use of the questionnaire are contained in the following section.

Use of Questionnaire A

A. The information entered in this section will appear on the first page of the output.

B1. First half of year is A; second half is B. Example, 1966A.

B2. Program is designed to handle a maximum of 20 input sets.

B3. This is Output II of Figure 2-4.

B4. This is Output III of Figure 2-4.

B5. Ordinarily, all sets inputted would be outputted. However, the output may be restricted to some number of sets less than in the input.

B6. If start dates are not specified, a nominal schedule will be used
B7. for each vehicle.

C. For convenience in relating vehicles to missions in printout. Unless otherwise desired, the numbers 1 through 20 will suffice.

D. Vehicles are handled within the computer by the vehicle number appearing in Tables D-1 through D-3.

E. Dates required correspond to the mission dates of Questionnaire G. Dates in this section are entered as 66A, 67B, etc.

F. Start dates are entered in same form as in E; i. e., 67A, etc. In the costing process, if a start date is specified and the vehicle being costed is a repeat article, the computer program will ignore the inputed start date and set the start date two half-years prior to the date required.

LUNAR SURFACE MOBILITY SYSTEMS
COMPARISON AND EVOLUTION STUDY (MOBEV)

PLANNER'S INPUT QUESTIONNAIRE A

VEHICLE COSTING

THE BENDIX CORPORATION
BENDIX SYSTEMS DIVISION
ANN ARBOR, MICHIGAN

A. PROBLEM IDENTIFICATION

Complete A1 through A3 as needed.

A1. Enter run number

A2. Enter date

A3. Enter problem description

B. PROBLEM CONTROL

B1. Enter present half year (1966A, etc.)

B2. Enter number of sets in input.
Maximum number permissible is 20.

Select one of B3. or B4.

The desired output is . . . .

B3. (1) Vehicles in each set
(2) Cost of each set
(3) Cost of each vehicle
(4) Development start date for each vehicle

B4. Output B3. plus. . . .

(1) Committed and expanded funds by half year, per vehicle and per set

Complete B5.

B5. Enter the number of sets to be included in the output. This will generally be the same as, but must not exceed B2.

Select one of B6. or B7.

Development start dates for each vehicle . . . .

B6. Will be specified

B7. Will not be specified

C. MISSION IDENTIFICATION

C1. This column is not used.

C2. Through C21.

Enter any mission numbers (e.g., 1 through 20) for vehicle-mission identification in output.

Sections D and E must be completed for each vehicle set. Maximum number of sets permissible is 20.

D. VEHICLE SET SELECTIONS

D1. Enter set number (first is 1, etc.)

D2. Through D21.

Enter vehicle numbers (from current vehicle listing) for all vehicles in this set.

E. DATES VEHICLES ARE REQUIRED

E1. Enter set number to agree with D1.

E2. Through E21.

Enter date each vehicle is required (67A, etc.). Each date is Section E must correspond to its vehicle in Section D.

If B6 was chosen in Section B, go to Section F.

If B7 was chosen in Section B, and Sections D and E have been completed for all sets, your input questionnaire is complete.

F. DEVELOPMENT START DATES

F1. Enter set number to agree with D1.

F2. Through F21.

Enter start date for each vehicle in set (66B, etc.). Each date must correspond to its vehicle in Section D.

If Sections D, E, and F have been completed for all sets, your input questionnaire is complete.

C. Mission Identification

C1.

Mission Numbers

C2.	1st Mission
C3.	2nd Mission
C4.	etc
C5.	
C6.	
C7.	
C8.	
C9.	
C10.	
C11.	
C12.	
C13.	
C14.	
C15.	
C16.	
C17.	
C18.	
C19.	
C20.	
C21.	

Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV)

B. Problem Control

B1. Present Half-Year	
B2. No. of Input Sets	
Output	B3. Total Costs
	B4. Spread Costs
B5. No. of Output Sets	
Start Dates	B6. Specified
	B7. Not Specified

A. Problem Identification

A

A1. Run Number

A2. Date — Month / Day / Year

A3. Problem Description

Figure 2-5 Planner's Input Questionnaire A Answer Sheet - Vehicle Costing - Sheet 1 of 2

F. Development Start Dates	
F1. Set Number	
Start Dates	F2. 1st Vehicle
	F3. 2 nd
	F4. etc
	F5.
	F6.
	F7.
	F8.
	F9.
	F10.
	F11.
	F12.
	F13.
	F14.
	F15.
	F16.
	F17.
	F18.
	F19.
	F20.
	F21.

E. Dates Vehicles Required	
E1. Set Number	
Dates Req'd	E2. 1st Vehicle
	E3. 2nd Vehicle
	E4. etc
	E5.
	E6.
	E7.
	E8.
	E9.
	E10.
	E11.
	E12.
	E13.
	E14.
	E15.
	E16.
	E17.
	E18.
	E19.
	E20.
	E21.

D. Vehicle Set Selections	
D1. Set Number	
Vehicle Numbers	D2. 1st Vehicle
	D3. 2nd Vehicle
	D4. etc
	D5.
	D6.
	D7.
	D8.
	D9.
	D10.
	D11.
	D12.
	D13.
	D14.
	D15.
	D16.
	D17.
	D18.
	D19.
	D20.
	D21.

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Figure 2-6 Planner's Input Questionnaire A
Answer Sheet - Vehicle Costing - Sheet 2 of 2

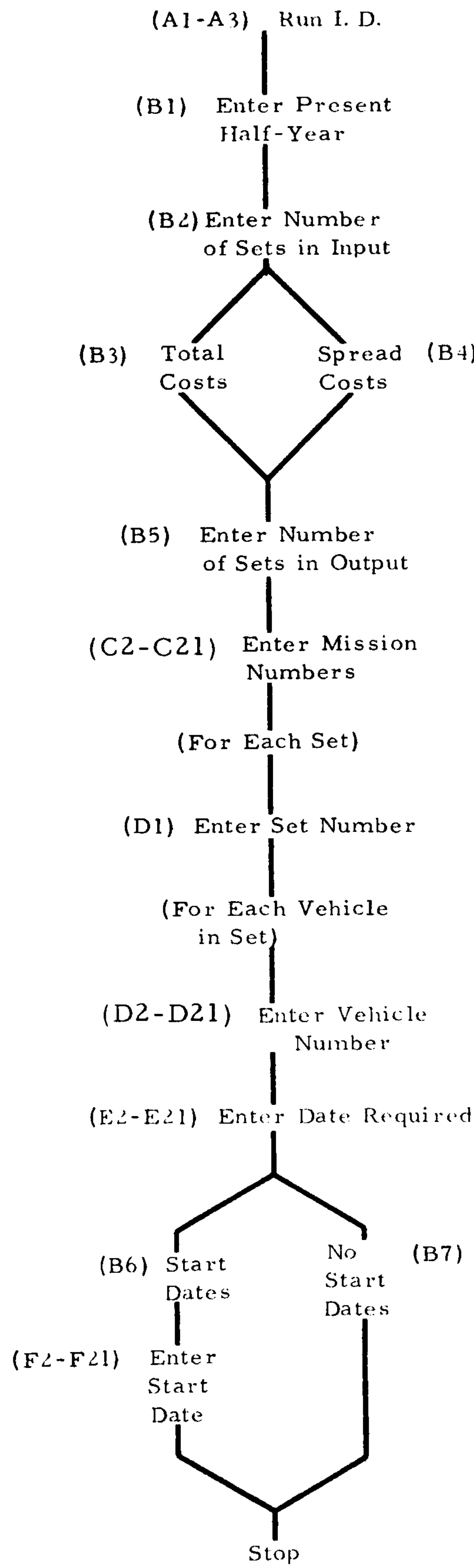

Figure 2-7 Logic Tree - Questionnaire A Vehicle Costing

2.3.2 Vehicle Selection Plus Costing

The format for this questionnaire is the same as that for costing only. This questionnaire is somewhat more lengthy because of the mission inputs required. The answer sheet is again completed directly from the questionnaire, (Figures 2-8, 2-9, and 2-10). All entires on the answer sheet must be right justified. Selections are made by entering a one (1) in the appropriate column of the answer sheet. The answer sheet is then ready for keypunching.

The logic tree (Figure 2-11) corresponding to this questionnaire is found immediately following the answer sheets and may be of aid in summarizing the questionnaire. Comments on the use of the questionnaire follow below.

Use of Questionnaire G

G. The information entered in this section will appear on the first page of the output.

H1. First half of year is A; second half is B. Example, 1966A.

H2. Program is designed to handle a maximum of 20 input sets.

H4. The number of sets to be costed may be limited by this input.

Thus, if the user wishes to guard against an excessive use of computer time, the computer can be stopped through this input when the number of sets exceeds the limit entered.

H6. This is Output I of Figure 2-4

H7 This is Output IV of Figure 2-4

H8. This is Output V of Figure 2-4

H9. By entering a limit here, the user can prevent the printing of an excessive amount of output.

H11. The user may limit the vehicles to be considered and thereby save computer time by selecting this option.

H12. H13. An adjunct vehicle is one carried aboard a parent vehicle during a mission. For example, a Flyer may be carried on a Rover as an emergency measure. This constraint is not imposed until after set generation. It is not, therefore, included in the vehicles listed in Output I.

I. Candidate vehicles to be considered should be entered by vehicle number from Tables D-1, D-2, and D-3 and must be in ascending order for each mission.

K. The combined mass of several missions may be limited by completing this section. This constraint is not imposed until after set generation. It is not, therefore, included in the vehicles listed in Output I.

L1. For identification purposes in output.

L2. This is the half year during which mission is to take place. Enter full year, 1966A, etc.

L3. This saves completion of the remaining sections for identical mission requirements.

M3., M4. See Glossary.

N2., N3. See Glossary.

N8. Through N11.
A mission leg is a distance traveled between stops. A rescue mission will probably consist of one or two legs, corresponding to one-way and two-way rescues.

N12. Total time includes travel and stay-time at point of rescue.

N14., N15. Consider remote operation both for initial rendezvous, if necessary, and for normal rescue travel.

O2., O3. See Glossary.

O7. Mission payload is the total carried to the lunar surface. This may be taken out in total or in part on various sorties.

O8., O9. This selection refers to whether refueling will be allowed. Refueling of all flyers is technically feasible.

O20., O21. Consider remote operation both for initial rendezvous, if necessary, and for normal exploratory travel.

O22., O23. If O2 was selected, select O22,
If O3 was selected, select O23.

O24. Storage time is entered to account for cryogenic losses during storage.

P2., P3. See Glossary.

LUNAR SURFACE MOBILITY SYSTEMS
COMPARISON AND EVOLUTION STUDY (MOBEV)

PLANNER'S INPUT QUESTIONNAIRE G

VEHICLE SELECTION AND COSTING

THE BENDIX CORPORATION
BENDIX SYSTEMS DIVISION
ANN ARBOR, MICHIGAN

G. PROBLEM IDENTIFICATION

Complete G1 through G3 as needed.

G1. Enter run number

G2. Enter date

G3. Enter problem description

H. PROBLEM CONTROL

H1. Enter present half year (1966A, etc.)

H2. Enter number of missions in input. Maximum permissible is 20.

Choose one of H3 and H4 if costing is to be done.

The number of sets to be processed . . . .

H3. Will not be limited

H4. Will be limited

If H4 was chosen, complete H5.

H5. Enter maximum number of sets to be processed

Choose one of H6, H7, or H8.

The desired output is . . . .

H6. Acceptable vehicles for each mission, plus mass utilization for each vehicle.

H7. Output H6 plus . . . .

(1) Vehicles in each set
(2) Cost of each set
(3) Cost of each vehicle
(4) Development start date for each vehicle.

H8. Output H7 plus . . . .

(1) Committed and expended funds by half year, per vehicle and per set

If either H7 or H8 was chosen, complete H9.

H9. Enter the number of sets to be included in the output. Maximum permissible is 20.

Choose one of H10 or H11.

You wish to consider . . . .

H10. All vehicles in the library for each mission

H11. Only certain candidate vehicles from the library for each mission

Choose one of H12 or H13.

Adjunct vehicles are . . . .

H12. Used

H13. Not used

Choose one of H14 or H15.

The combined mass limits for two or more missions are . . .

H14. Used

H15. Not used

I. CANDIDATE VEHICLES

Complete this section if H11 was chosen.

I1. through I20.

Enter mission identification numbers and vehicles to be considered for each mission. Vehicle numbers must be in ascending order for each mission.

J. ADJUNCT VEHICLES

Complete this section if H12 was chosen. These constraints are not imposed until after set generation. They will not, therefore, be included in the vehicles listed in Output H6.

J1. through J4.

Enter mission number for both parent and adjunct vehicles.

K. COMBINED MISSION MASS LIMITS

Complete this section if H14 was chosen. These constraints are not imposed until after set generation. They will not, therefore, be included in the vehicles listed in Output H6.

K1. through K4.

Enter mass limit in kilograms and missions affected.

L. MISSION REQUIREMENTS

Section L and applicable Sections M through P must be completed for each mission.

L1. Enter mission number

If either H7 or H8 was chosen complete L2.

L2. Enter mission date (1965A, etc.)

If this mission is identical to a previous mission, except for the mission date, complete L3.

L3. Enter mission number of the first of the identical missions. Then go to next mission.

Choose one of L4 through L7.

This mission is classed as . . . .

L4. Return-to-orbit

L5. Surface Rescue

L6. Exploration

L7. Base Support

M. RETURN-TO-ORBIT MISSION

Complete this section if L4 was chosen.

If the number of astronauts returning to orbit is to be specified, complete Ml.

Ml. Enter number returning to orbit

If a mass limit is to be imposed on this mission, complete M2 and select one of M3 or M4.

M2. Enter mass limit in kilograms

This mass limit applies to the . . .

M3. Unfueled mass

M4. Delivered fueled mass

Input for this mission is complete, go to next mission. If all missions are complete, your input is complete.

N. RESCUE MISSION

Complete this section if L5 was chosen.

If a mass limit is to be imposed on this mission, complete Nl and choose one of N2 or N3.

N1. Enter mass limit in kilograms

This mass limit applies to the ......

N2. Unfueled mass

N3. Delivered fueled mass

Choose one of N4, N5, or N6.

This vehicle for this mission ......

N4. Must be a flyer

N5. Must be a rover

N6. May be either flyer or rover

If a payload is to be specified, complete N7.

N7. Enter payload in kilograms

Complete N8 through N11.

N8. Through N11.

Enter range in kilometers and total number in crew for each mission leg.

If a time limit is to be imposed on the rescue operation, complete N12.

N12. Enter total rescue duration in hours to nearest tenth. This is the total time to complete the legs listed in N8 through N11.

If N4 was chosen, mission is complete. Go to next mission. If all missions are complete, your input is complete. Otherwise continue below.

Complete N13.

N13. Choose one surface model for Rovers.

Choose one of N14 or N15.

Remote control of Rovers considered for this mission ......

N14. Required

N15. Not required

Input for this mission is complete, go to next mission. If all missions are complete, your input is complete.

O. EXPLORATION MISSION

Complete this section if L6 was chosen.

If a mass limit is to be imposed on this mission complete O1 and choose one of O2 or O3.

O1. Enter mass limit in kilograms ......

This mass limit applies to the ......

O2. Unfueled mass

O3. Delivered fueled mass

Choose one of O4, O5, or O6.

The vehicle for this mission ......

O4. Must be a Flyer

O5. Must be a Rover

O6. May be either Flyer or Rover

If a payload will be specified for any sorties of this mission, complete O7.

O7. Enter mission payload. This is the total payload to be delivered to the moon and may be greater than that portion carried on any one sortie.

If O4 or O6 was chosen, choose one of O8 or O9.

O8. Flyers cannot be refueled

O9. Flyers can be refueled

Again, if either O4 or O6 was chosen, complete O10 through O13.

O10. Through O13.

Enter total time required for each sortie, including travel and on-station in hours.

If O5 or O6 was chosen, complete O14 through O19.

O14. Enter maximum range from shelter during any sortie (km).

O15. Choose one surface model for Rovers.

O16. Through O19.

Enter total time required for each sortie including travel and on-station in days.

Again, if O5 or O6 was chosen, choose one of O20 or O21.

Remote control of Rovers during this mission is ......

O20. Required

O21. Not required

Again, if O5 or O6 was chosen, choose one of O22 or O23. This choice must be consistent with O2 and O3.

Rovers will be delivered to the lunar surface ......

O22. Unfueled

O23. Fueled

If O23 was chosen and storage on the lunar surface is required, complete O24.

O24. Enter storage time in months

Complete O25 through O28.

O25. Through O28.

For each sortie enter payload in kilograms, number of astronauts in crew, and range of each sortie leg (km).

Input for this mission is complete, go to next mission. If all missions are complete, your input is complete.

P. BASE SUPPORT MISSION

Complete this section if L7 was chosen.

If a mass limit is to be imposed on this mission complete P1 and choose one of P2 or P3.

P1. Enter mass limit in kilograms

This mass limit applies to the ......

P2. Unfueled mass

P3. Delivered fueled mass

If drawbar pull is to be specified, complete P4.

P4. Enter drawbar pull in pounds.

If appendages are required, complete P5.

P5. Choose appendages required

If cargo capacity is to be specified, complete P6.

P6. Enter cargo capacity in kilograms

If range/sortie is to be specified, complete P7.

P7. Enter range/sortie in kilometers

If sortie duration is to be specified, complete P8.

P8. Enter sortie duration in hours to nearest tenth

Input for this mission is complete, go to next mission. If all missions are complete, your input is complete.

I. Candidates - Card 2		
I5 Fifth Mission	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I6	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I7	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I8 Eighth Mission	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc

I. Candidates - Card 1		
I1 First Mission	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I2 Second Mission	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I3 Third Mission	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc
I4 ETC	Mission Number	
	Candidate Vehicles	1st
		2nd
		etc

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H. Problem Control	
H1. Present Half-Year	
H2. No. of Input Missions	
Sets To be Processed	H3. No Limit
	H4. Limit
	H5. No. of Sets
Output	H6. Acceptable Vehicles
	H7. Total Costs
	H8. Spread Costs
	H9. No. of Sets
Vehicle Library.	H10. All
	H11. Candidates
Adjunct Vehicles	H12. Used
	H13. Not Used
Combined Mass Limits	H14. Used
	H15. Not Used

G. Problem Identification	
G1. Run Number	
G2. Date	Month
	Day
	Year
G3. Problem Description	

Figure 2-8 Planner's Input Questionnaire G Answer Sheet - Vehicle Selection and Costing - Sheet 1 of 3

J. Adjunct Vehicles		Columns
J1. First Combination	Adjunct Mission	1 2 3
	Parent Mission	4 5 6
J2. Second Combination	Adjunct Mission	7 8 9
	Parent Mission	10 11 12
J3. Third	Adjunct Mission	13 14 15
	Parent Mission	16 17 18
J4. Fourth	Adjunct Mission	19 20 21
	Parent Mission	22 23 24

K. Combined Mass Limits			Columns
K1. First Limit	Mass Limit (kg)		1 2 3 4 5
	Mission Numbers	1st	6 7 8
		2nd	9 10 11
		3rd	12 13 14
K2. Second Limit	Mass Limit (kg)		15 16 17 18 19
	Mission Numbers	1st	20 21 22
		2nd	23 24 25
		3rd	26 27 28
K3. Third Limit	Mass Limit (kg)		29 30 31 32 33
	Mission Numbers	1st	34 35 36
		2nd	37 38 39
		3rd	40 41 42
K4. Fourth Limit	Mass Limit (kg)		43 44 45 46 47
	Mission Numbers	1st	48 49 50
		2nd	51 52 53
		3rd	54 55 56

I. Candidates - Card 5			Columns
I17. Seventeenth Mission	Mission Number		1 2 3
	Candidate Vehicles	1st	4 5 6
		2nd	7 8 9
		etc	10 11 12
			13 14 15
			16 17 18
I18. Eighteenth Mission	Mission Number		19 20 21
	Candidate Vehicles	1st	22 23 24
		2nd	25 26 27
		etc	28 29 30
			31 32 33
			34 35 36
I19. Nineteenth Mission	Mission Number		37 38 39
	Candidate Vehicles	1st	40 41 42
		2nd	43 44 45
		etc	46 47 48
			49 50 51
			52 53 54
I20. Twentieth Mission	Mission Number		55 56 57
	Candidate Vehicles	1st	58 59 60
		2nd	61 62 63
		etc	64 65 66
			67 68 69
			70 71 72

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I. Candidates - Card 4			Columns
I13. Thirteenth Mission	Mission Number		1 2 3
	Candidate Vehicles	1st	4 5 6
		2nd	7 8 9
		etc	10 11 12
			13 14 15
			16 17 18
I14. Fourteenth Mission	Mission Number		19 20 21
	Candidate Vehicle	1st	22 23 24
		2nd	25 26 27
		etc	28 29 30
			31 32 33
			34 35 36
I15. Fifteenth Mission	Mission Number		37 38 39
	Candidate Vehicles	1st	40 41 42
		2nd	43 44 45
		etc	46 47 48
			49 50 51
			52 53 54
I16. Sixteenth Mission	Mission Number		55 56 57
	Candidate Vehicles	1st	58 59 60
		2nd	61 62 63
		etc	64 65 66
			67 68 69
			70 71 72

I. Candidates - Card 3			Columns
I9. Ninth Mission	Mission Number		1 2 3
	Candidate Vehicles	1st	4 5 6
		2nd	7 8 9
		etc	10 11 12
			13 14 15
			16 17 18
I10. Tenth Mission	Mission Number		19 20 21
	Candidate Vehicles	1st	22 23 24
		2nd	25 26 27
		etc	28 29 30
			31 32 33
			34 35 36
I11. Eleventh Mission	Mission Number		37 38 39
	Candidate Vehicles	1st	40 41 42
		2nd	43 44 45
		etc	46 47 48
			49 50 51
			52 53 54
I12. Twelfth Mission	Mission Number		55 56 57
	Candidate Vehicles	1st	58 59 60
		2nd	61 62 63
		etc	64 65 66
			67 68 69
			70 71 72

Figure 2-9 Planner's Input Questionnaire G
Answer Sheet - Vehicle Selection and Costing -
Sheet 2 of 3

P. Base Support

Mass Limit
- P1. Mass (kg)
- P2. Unfueled
- P3. Delivered Fueled

P4. Drawbar Pull (lb)

P5. Appendages
- Backhoe
- Bulldozer Blade

P6. Cargo Capacity (kg)

P7. Range/Sortie (km)

P8. Sortie Duration — Hrs . Tenths

O. Exploration - Card 2

O26. 2nd Sortie
- Payload (kg)
- Crew
- Ranges (km): 1st Leg, 2nd Leg, 3rd Leg, 4th Leg

O27. 3rd Sortie
- Payload (kg)
- Crew
- Ranges (km): 1st Leg, 2nd Leg, 3rd Leg, 4th Leg

O28. 4th Sortie
- Payload (kg)
- Crew
- Ranges (km): 1st Leg, 2nd Leg, 3rd Leg, 4th Leg

O. Exploration - Card 1

Mass Limit
- O1. Mass (kg)
- O2. Unfueled
- O3. Delivered Fueled

Vehicle Req'd
- O4. Flyer
- O5. Rover
- O6. Flyer or Rover

O7. Mission Payload (kg)

Flyer Refueling
- O8. No
- O9. Yes

Sortie Times (Flyers)
- O10. 1st — Hours . Tenths
- O11. 2nd — Hours . Tenths
- O12. 3rd — Hours . Tenths
- O13. 4th — Hours . Tenths

O14. Max Range From Shelter (km) (Rovers)

O15. Surface Model (Rovers)
- ELMS Maria
- ELMS Highlands
- ELMS 50-50

Sortie Times (Rover)
- O16. 1st — Days . Tenths
- O17. 2nd — Days . Tenths
- O18. 3rd — Days . Tenths
- O19. 4th — Days . Tenths

Rover Remote Control
- O20. Req'd
- O21. Not Req'd

Rover Delivery
- O22. Unfueled
- O23. Fueled

O24. Rover Storage (Months)

O25. 1st Sortie
- Payload (kg)
- Crew
- Ranges (km): 1st Leg, 2nd Leg, 3rd Leg, 4th Leg

L. Mission Requirements

L1. Mission Number

L2. Mission Date

L3. Same as Mission . . .

Mission Class
- L4. Return-to-Orbit
- L5. Surface Rescue
- L6. Exploration
- L7. Base Support

M. Return-To-Orbit

M1. Astronauts Returning

Mass Limit
- M2. Mass (kg)
- M3. Unfueled
- M4. Fueled

N. Surface Rescue

Mass Limit
- N1. Mass (kg)
- N2. Unfueled
- N3. Delivered Fueled

Vehicle Req'd
- N4. Flyer
- N5. Rover
- N6. Flyer or Rover

N7. Payload (kg)

Mission Legs
- N8. 1st — Range (km), Crew
- N9. 2nd — Range (km), Crew
- N10. 3rd — Range (km), Crew
- N11. 4th — Range (km), Crew

N12. Rescue Duration — Hours . Tenths

N13. Surface Model
- ELMS Maria
- ELMS Highlands
- ELMS 50-50

Rover Remote Control
- N14. Req'd
- N15. Not Req'd

Lunar Surface Mobility Systems Comparison and Evolution Study (MOBEV)

Figure 2-10 Planner's Input Questionnaire G Answer Sheet - Vehicle Selection and Costing - Sheet 3 of 3

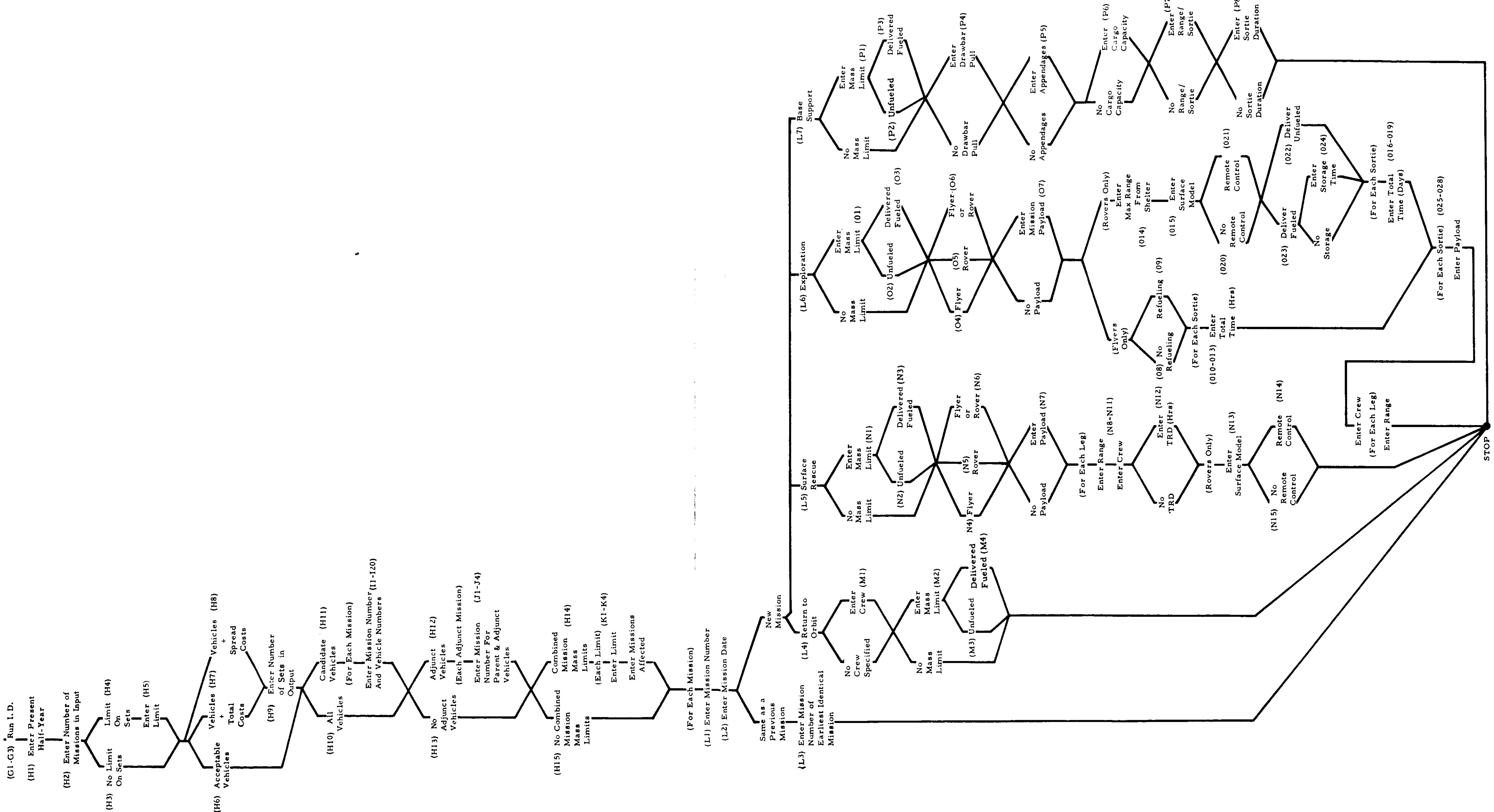


Figure 2-11 Logic Tree - Questionnaire Vehicle Selection Plus Costing

2.4 OUTPUT

As mentioned in the discussion of the overall logic in Section 2.2, there are five outputs available from the computer program. Actually there are only three distinct outputs, Outputs II and IV being similar and Outputs III and V also being similar. The reason for labeling these separately is to retain the association of the output with the type of problem being run.

2.4.1 Output I

The simplest output available, Output I, may be called for immediately following vehicle tests as shown in Figure 2-4. This output lists the vehicles accepted for each mission inputted and the mass utilization of each. Vehicles are listed by number (currently 1 through 33). Flyers, Rovers, and Prime Movers appear to the left of the dash in the output format. If trailers are selected these appear following the dash of the associated prime mover. If no trailers are selected the trailer printout position is zero. A sample of this output is shown in Figure 2-12. The number of sets of vehicles possible is also calculated and printed. This number is the product of the total numbers of vehicles listed under each mission.

2.4.2 Outputs II and IV

These outputs, as seen from Figure 2-4 are available following set generation and costing. The difference between the two outputs is that Output IV contains a listing of vehicles selected, since the right hand side of Figure 2-4 is being used, (missions specified). In addition, Output IV contains a listing of the total cost of each set and each vehicle within each set, as well as the development start date for each vehicle if this was not specified in the input.

```
                                          MISSIONS

    1     2     3     5     7     9    10    11    13    15     0     0     0     0     0     0     0     0     0     0

                                     ACCEPTABLE VEHICLES

19- 0 19- 0 19- 0 19- 0 22- 0 24- 0 24- 0 24- 0 24- 0 24- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0
20- 0 20- 0 20- 0 26- 0 23- 0 26- 0 26- 0 26- 0 26- 0 26- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0
 0- 0  0- 0  0- 0  0- 0 24- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0
 0- 0  0- 0  0- 0  0- 0 25- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0
 0- 0  0- 0  0- 0  0- 0 26- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0  0- 0


NO. OF SETS THAT CAN BE GENERATED =          2560

ACCEPTED VEHICLE  19   FOR MISSION   5
         EXPENDABLES AVAILABLE (W0)   .   .   .   .   .   .   .   .              =    601.00
                     STORAGE LOSSES (WE)                       =       .0
                     EGRESS/INGRESS + EVA LOSSES (W3)          =       .0
                     MOBILITY EXPENDABLES (W1)                 =    32.64
                     LIFE SUPPORT EXPENDABLES (W2)             =    29.50
                     PAYLOAD                                   =   100.00
                     CREW MASS (CM)                            =   142.00
                                                                ---.-----
                ALLOCATED MASS (AM)                            =   304.14  .  .  .  .  .  .  -    304.14
                   + UNFUELED MASS (UM)                        +   266.10                       ---------
                   + MISSION PAYLOAD (MPL)                     -   100.00       MASS MARGIN (MM) =    296.86
                   - CREW MASS (CM)                            -   142.00
                   - SORTIE PAYLOAD (PL)                       =   100.00
                                                                ---.-----
                DELIVERED FUELED MASS (DFM)                    =   428.24

REJECTED VEHICLE  19   FOR MISSION   7
         VEH. LACKS REMOTE CONTROL.

REJECTED VEHICLE  19   FOR MISSION   9
         VEH. LACKS REMOTE CONTROL.

REJECTED VEHICLE  19   FOR MISSION  10
         VEH. LACKS REMOTE CONTROL.

REJECTED VEHICLE  19   FOR MISSION  11
         VEH. LACKS REMOTE CONTROL.

REJECTED VEHICLE  19   FOR MISSION  13
         VEH. LACKS REMOTE CONTROL.
```

Figure 2-12 Printout-Cutput I

Output II is identical to Output IV except that it contains no listing of vehicle selections. Output II is called for when costing only is being run and vehicles are not selected, but must be inputed. Samples of Outputs II and IV are shown as labeled in Figure 2-13.

2.4.3 Outputs III and V

These outputs bear the same relation to each other as do Outputs II and IV. Output III is used when costing only; Output V is used when vehicle selection plus costing is used. Both outputs are available following cost spreading as seen in Figure 2-4. In this subroutine, the total cost, as would be contained in Outputs II and IV, are distributed or spread on a half-year basis over the vehicle development time. Thus, Outputs III and V include the spread costs for each vehicle and each set, and also include the complete information on total costs in Outputs II and IV. A sample of cost spreading as contained in Outputs III and V is shown as Figure 2-14.

OUTPUT IV

MISSIONS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	0	0	0	0

ACCEPTABLE VEHICLES

3- 0	3- 0	3- 0	5- 0	3- 0	5- 0	22- 0	6- 0	24- 0	24- 0	24- 0	0- 0	24- 0	0- 0	24- 0	0- 0	0- 0	0- 0	0- 0	0- 0
5- 0	5- 0	5- 0	6- 0	5- 0	6- 0	23- 0	7- 0	26- 0	26- 0	26- 0	0- 0	26- 0	0- 0	26- 0	0- 0	0- 0	0- 0	0- 0	0- 0
6- 0	6- 0	6- 0	7- 0	6- 0	7- 0	24- 0	10- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0
9- 0	9- 0	9- 0	9- 0	9- 0	9- 0	25- 0	11- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0
0- 0	0- 0	0- 0	10- 0	0- 0	10- 0	26- 0	12- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0
0- 0	0- 0	0- 0	11- 0	0- 0	11- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0
0- 0	0- 0	0- 0	12- 0	0- 0	12- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0	0- 0

OUTPUT II

COST BREAKDOWN OF LEAST EXPENSIVE ACCEPTABLE SETS

SET 1

MISSION	VEHICLE	COST	START DATE
1	6	32118976.	1967 A
2	6	2195000.	1970 B
3	6	2083000.	1971 B
4	6	1996000.	1971 B
5	6	1925000.	1972 B
6	6	1869000.	1972 B
7	26	343470080.	1969 A
8	6	1815000.	1973 A
9	26	14490000.	1974 A
10	26	14070000.	1975 A
11	26	13680000.	1976 A
12	32	62750016.	1973 B
13	26	13350000.	1977 A
14	32	5545000.	1977 A
15	26	13080000.	1978 A
16	32	5359000.	1978 A

		529796608.	

SET 2

MISSION	VEHICLE	COST	START DATE
1	3	19128000.	1968 A
2	3	1596000.	1970 B
3	3	1514000.	1971 B
4	[illegible]	27498944.	1969 A
5	3	1451000.	1972 B
6	6	2195000.	1972 B
7	26	343470080.	1969 A

Figure 2-13 Printout-Outputs I and IV

SET 1 COST SPREADING

HALF YEAR	COMMITIED	EXPENDED
1967 A	7869144.	2248328.
1967 B	9796200.	5139032.
1968 A	4400384.	6873472.
1968 B	4432416.	5363864.
1969 A	5521472.	17279104.
1969 B	8423144.	38125376.
1970 A	60235776.	44957248.
1970 B	34291328.	52705856.
1971 A	33163072.	49095468.
1971 B	35717504.	36549696.
1972 A	28468800.	37940736.
1972 B	20732400.	44982528.
1973 A	8478300.	37072320.
1973 B	19705200.	16786496.
1974 A	29160400.	21002112.
1974 B	13435576.	21725376.
1975 A	20063408.	18265280.
1975 B	8752700.	19022208.
1976 A	10963256.	13034696.
1976 B	3324240.	6292800.
1977 A	14303520.	10203296.
1977 B	4591400.	8691704.
1978 A	13956340.	9957056.
1978 B	4480600.	8481944.
	---------------	---------------
	529796608.	529795584.

SET 1, MISSION 1, VEHICLE 6

HALF YEAR	COMMITIED	EXPENDED
1967 A	7869144.	2248328.
1967 B	9796200.	5139032.
1968 A	4400384.	6873472.
1968 B	4432416.	5363864.
1969 A	3693600.	4914200.
1969 B	1796652.	5556576.
1970 A	128476.	2023496.
	---------------	---------------
	32116912.	32116912.

SET 1, MISSION 2, VEHICLE 6

HALF YEAR	COMMITIED	EXPENDED
1970 B	1661615.	1185300.
1971 A	533385.	1009700.
	---------------	---------------
	2195000.	2195000.

Figure 2-14 Cost Spreading in Outputs III and V

SECTION 3

APPLICATIONS

This section illustrates some of the possible applications of the Methodology Computer Program. The coverage is not intended to be complete since each user will undoubtedly find means of application not explicitly detailed here. However, sufficient indication of the program possibilities is contained in the following sections to show the types of problems and applications which can be explored.

Section 3.1 brings into focus the intent of the remaining sections by expanding somewhat on the objective of the entire section; Section 3.2 summarizes the ten distinct types of runs that may be made with the program; and Section 3.3 discusses the problem of selecting a mobility evolution.

3.1 OBJECTIVE

As discussed in Section 2-1 a planner of lunar surface missions is faced with an ever-changing set of mission requirements, funding constraints, etc. Because of this continual changing, it is likely that a mobility evolution selected as best in the current year will not look quite as attractive in the face of next year's conditions. Therefore, it must be understood that the Methodology Computer Program will not yield an evolution which can be labeled as "best for all time", but only best in the light of the then-current constraints. For example, an evolution which will result in an expected monotonically-increasing funding level from 1970-1980 may be fine if funding availability follows such a trend. If, however, funding available were to change markedly from that expected, an evolution selected on the basis of monotonically-increasing funding might require major adjustment.

The computer program can, therefore, only aid in the selection of an evolution for a given set of constraints. As indicated later in this section, it can, however, also aid in evaluating the sensitivity of any particular selection to changes in these constraints.

The following paragraphs suggest the types of studies which might be made towards the selection of an evolution. No recommended approach is given since the user must decide in each case what is required for his purposes.

3.2 SUMMARY OF INPUT-OUTPUT POSSIBILITIES

Familiarity with the overall logic diagram of Figure 2-4 and Input Questionnaires A and G of Section 2-3 will indicate that ten input-output combinations exist with this program. That is, through specifying or not specifying various inputs and outputs, a total of ten types of runs can be made. These are shown in Figure 3-1.

If Questionnaire A is being used (Vehicle Costing), only two input choices are available. Vehicles to be costed must be inputed, but the planner has the choice of whether to specify schedules. Schedules in this context refers to specifying a start date for development of each vehicle. Two outputs may be called for with Questionnaire A: (1) total costs and schedule or (2) total costs plus spreading of these costs on a half-year basis. The planner must decide which level of detail is germane to his problem.

If Questionnaire G is used (Vehicle Selection and Costing), missions must be inputed and candidate vehicles may or may not be specified. Three outputs are available:

1. Acceptable Vehicles (Output I)

2. Output I Plus Total Costs (Output IV)

3. Output IV Plus Spread Costs (Output V).

Development start dates are not specified using Questionnaire G since the vehicles to be selected are unknown beforehand. Once the vehicles are selected, these vehicles and specified start dates may be inputed using Questionnaire A.

In Figure 3-1, the major items to be completed or selected in the applicable questionnaires have been noted in parentheses.

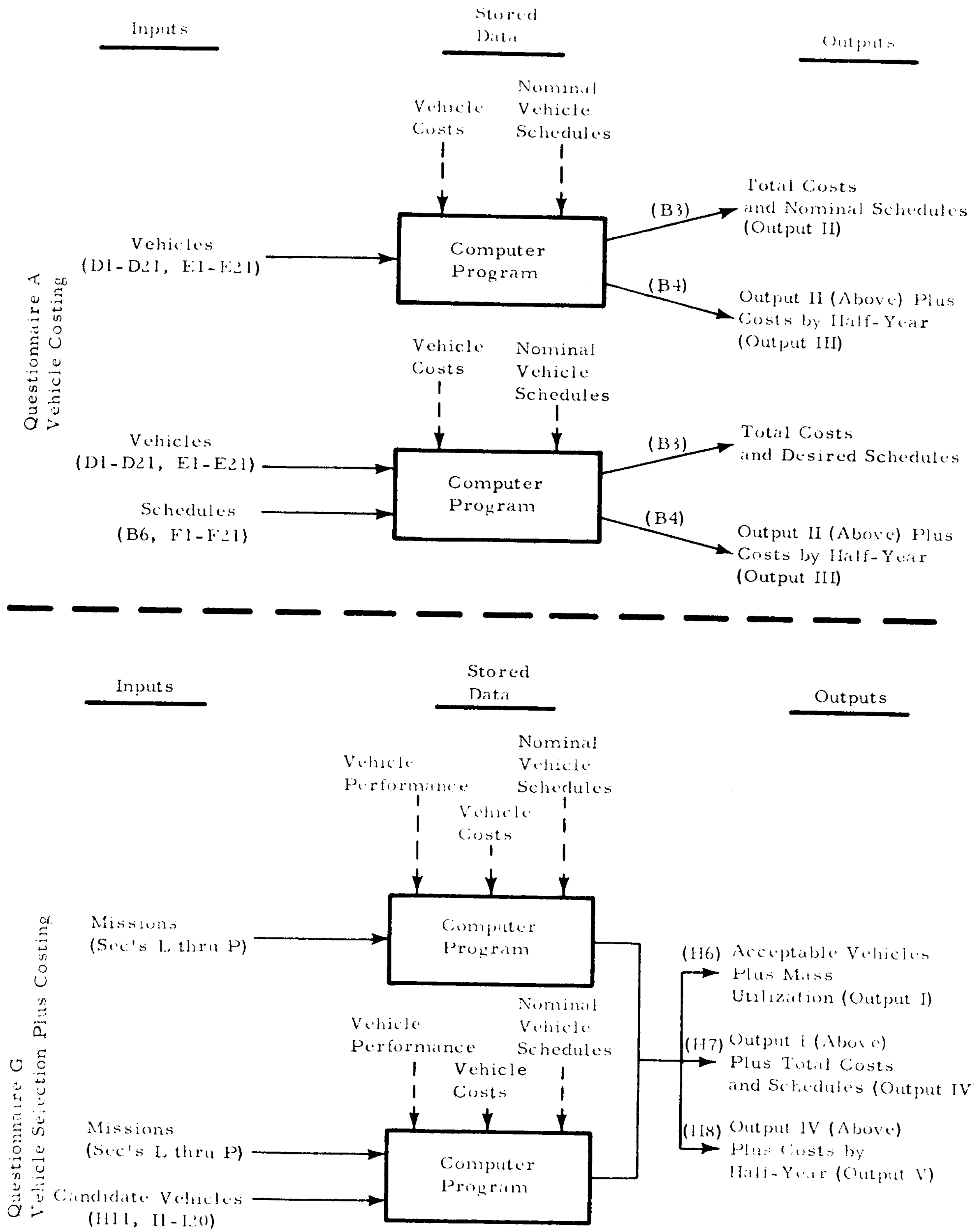


Figure 3-1 Input-Output Possibilities

3.3 SELECTION OF A PREFERRED MOBILITY EVOLUTION

As stated in Section 3.1 no recommended approach will be made as to the method of choosing a preferred mobility evolution. However, it is strongly felt that certain basic learning should be gained on first using the computer program so that the user may be aware of relationships underlying the results of a particular computer run.

Figure 3-2 makes this point more specifically. In the top portion is indicated what will be called here familiarization studies which are aimed at educating the user to the relationships between individual vehicular capabilities for individual missions, and the costs of individual vehicles. This educational process is covered in Section 3.1. Once the user is familar with vehicles, missions, and costs for singular vehicles, the second phase, indicated in the lower half of Figure 3-2, and called exploration program studies may be undertaken. Having completed the basic learning on the familiarization studies, the planner/user can now execute runs on the exploration program level without unknowingly masking important trends or conditions at the individual vehicle level. Section 3.3.2 discusses the exploration program studies.

3.3.1 Familiarization Studies

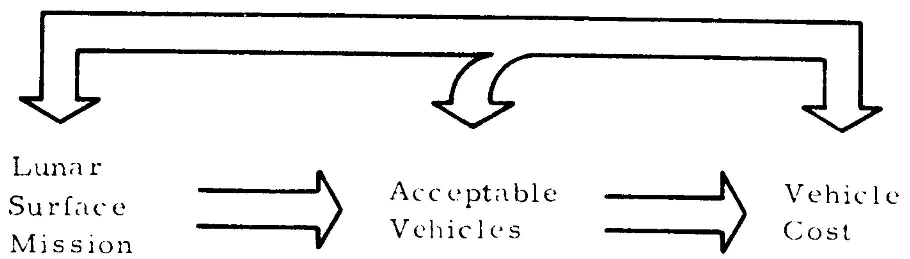
The goal of the familiarization studies is to acquaint the user with the relationships between missions, vehicles, schedules, and costs at the simplified level of singular missions and vehicles. Figure 2-1 showed two basic relationships which must be understood.

1. The relationship of vehicle to mission

2. The relationship among vehicle, schedule, and development cost.

During the learning process, a series of runs calling for vehicle selection only (Output I) would be useful. By employing only this part of the program, the user could, for example, get a feel for the vehicle gross weight required for a given mission. Figure 3-3 illustrates the type of result to be attained. Mission difficulty might be, more specifically, a combination of area covered, crew size, payload carried, and stay-time available.

Familiarization Studies



Exploration Program Studies

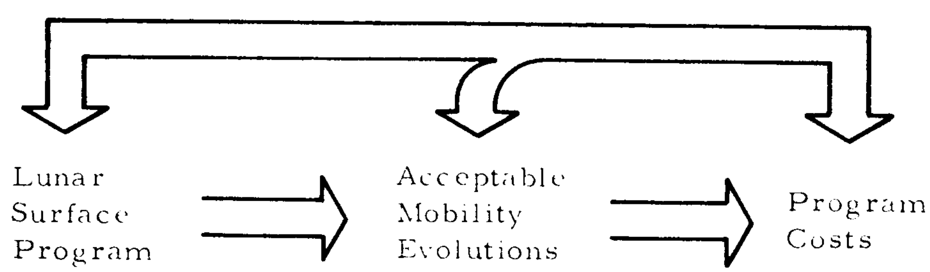


Figure 3-2 Selection of Mobility Evolution

In a similar manner, by running the computer program through to get total costs (Output IV), the costs of increasing mission difficulty could be explored. Figure 3-4 illustrates the type of result to be obtained. By perturbing the allowed development schedules (changing start dates using Questionnaire A), the effect of schedule constraints on vehicle costs could also be examined.

Studies such as those described above would be invaluable in appreciating the relationships involved in the upper portion of Figure 3-2.

3.3.2 Exploration Program Studies

The goal of these studies is the ultimate selection of a preferred evolution relative to a particular set of missions. With some degree of familiarization from the type of studies discussed in the previous section, the user now is able to better plan his runs in this phase.

Referring once again to Figure 3-2, in the lower portion, the runs to be made in this phase must help explain the interactions among exploration programs, vehicle sets or evolutions, and program costs. Output I during this phase has a less important role than during the familiarization runs except as it may serve as a convenient indicator of the number of sets to be costed (and therefore the computer time to be used). In this phase, rather, the interest is on total program costs as a first indicator of desirable evolutions. Thus, if the goal is to find those evolutions which are least costly, Outputs II and IV are available. Thus, a plot of the total cost of mobility systems for an exploration program of eight missions could be plotted as in Figure 3-5. This would indicate whether costs were really significantly different among the top contenders. At the same time, a plot of the total mass required on the moon for each vehicle evolution could also be plotted as in Figure 3-6, indicating in a general way the launch vehicle costs. Cross-plotting Figures 3-5 and 3-6 in Figure 3-7 would indicate the degree of correlation between total mass carried to the moon and evolutionary costs. Any seeming inconsistencies could then be investigated.

If the computer program were further exercised, with cost spreading (Outputs III and V) called for, the total costs in the above curves could be viewed for funding trends over the exploration program time (for example 1970-80). Figure 3-8 shows three types of funding curves which might be desired. By comparing the curves resulting from the computer runs, the most likely candidates from the least expensive evolutions could

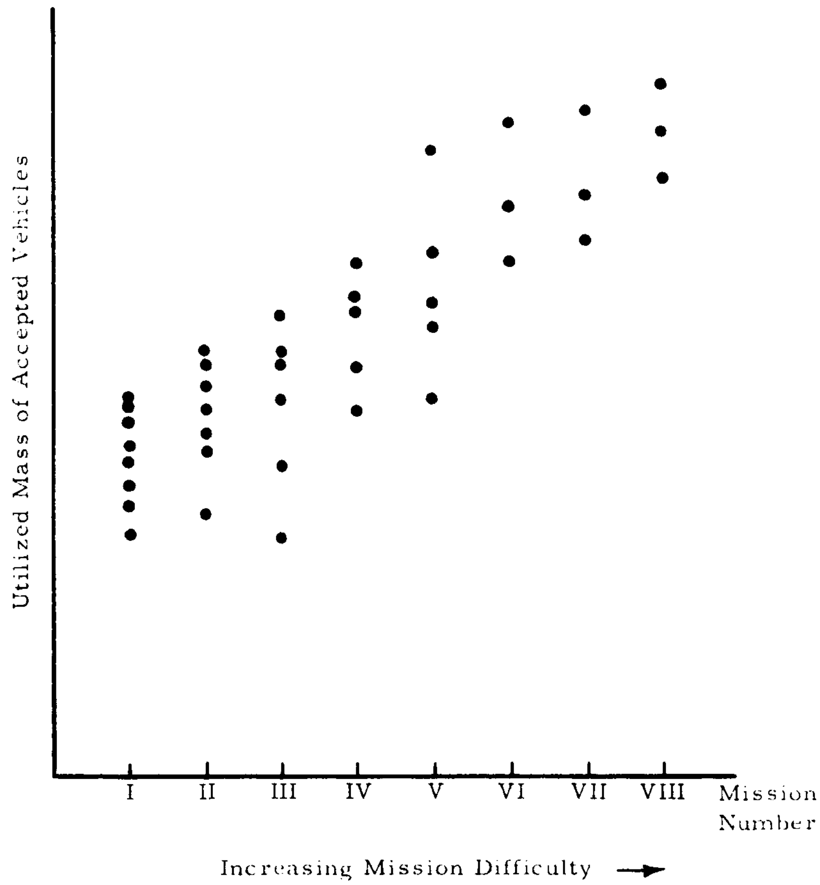


Figure 3-3 Vehicle Mass vs Mission Difficulty

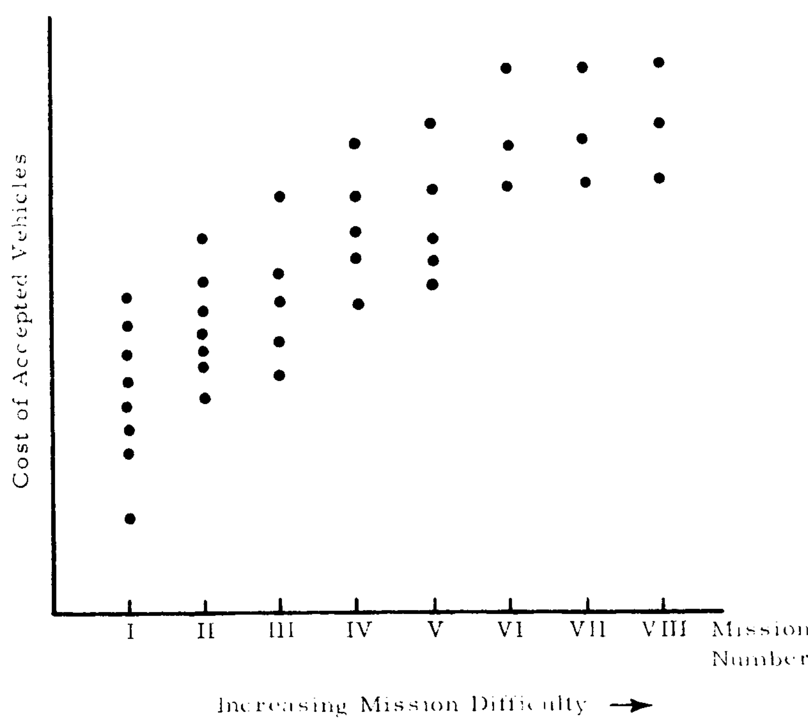


Figure 3-4 Vehicle Cost vs Mission Difficulty

be selected. Trial adjustments of the mission dates and/or development start dates could be made and the evolutions recosted in attempts to fit the estimated curve to the desired curve. Also, missions could be added, modified, or deleted.

In summary, after preliminary runs to define the most likely evolutions based on total costs, further narrowing of the candidate evolutions could be made on the basis of funding trends, with adjustments in the exploration program being made if necessary. Final selection might be based on studies made to select the evolution exhibiting the least sensitivity to changes in mission requirements.

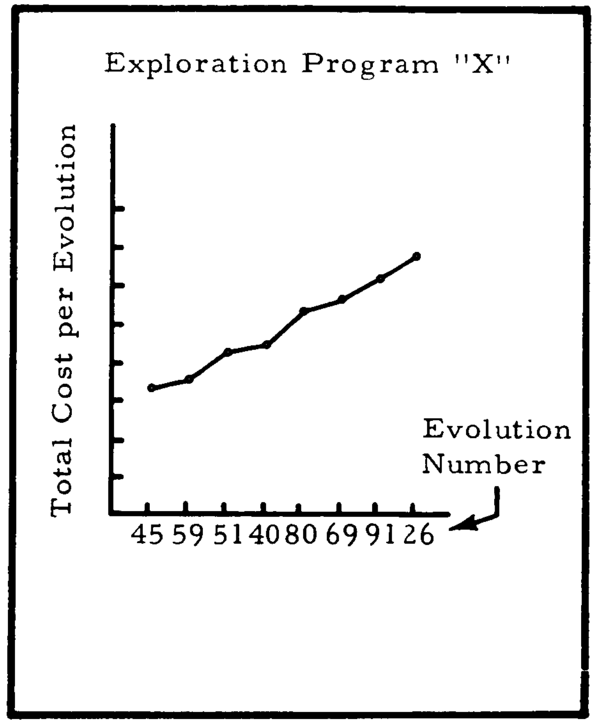


Figure 3-5 Total Cost per Evolution

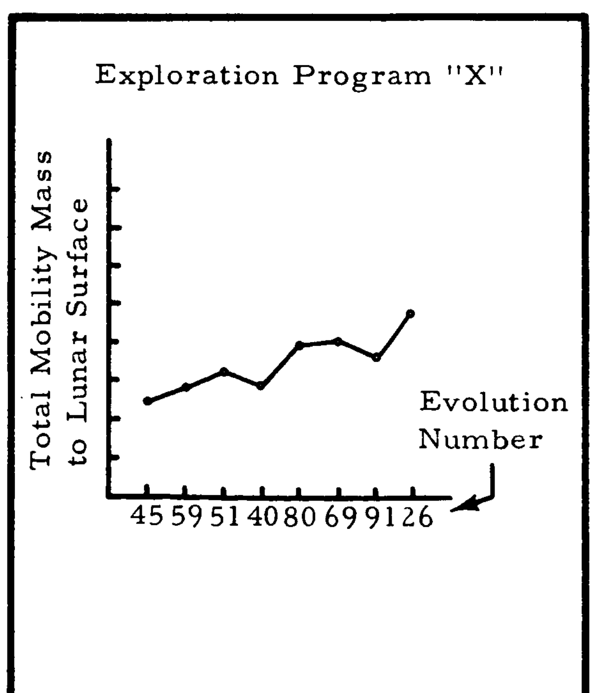


Figure 3-6 Total Mobility Mass to Lunar Surface

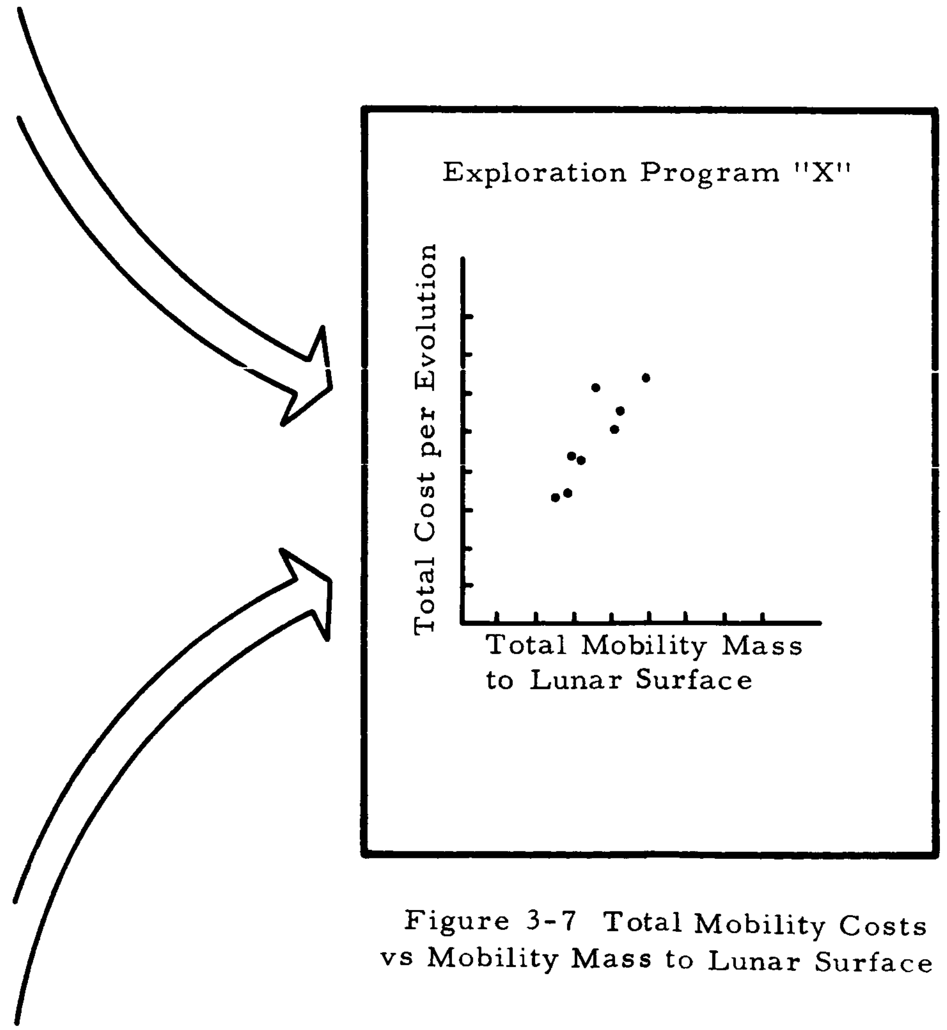


Figure 3-7 Total Mobility Costs vs Mobility Mass to Lunar Surface

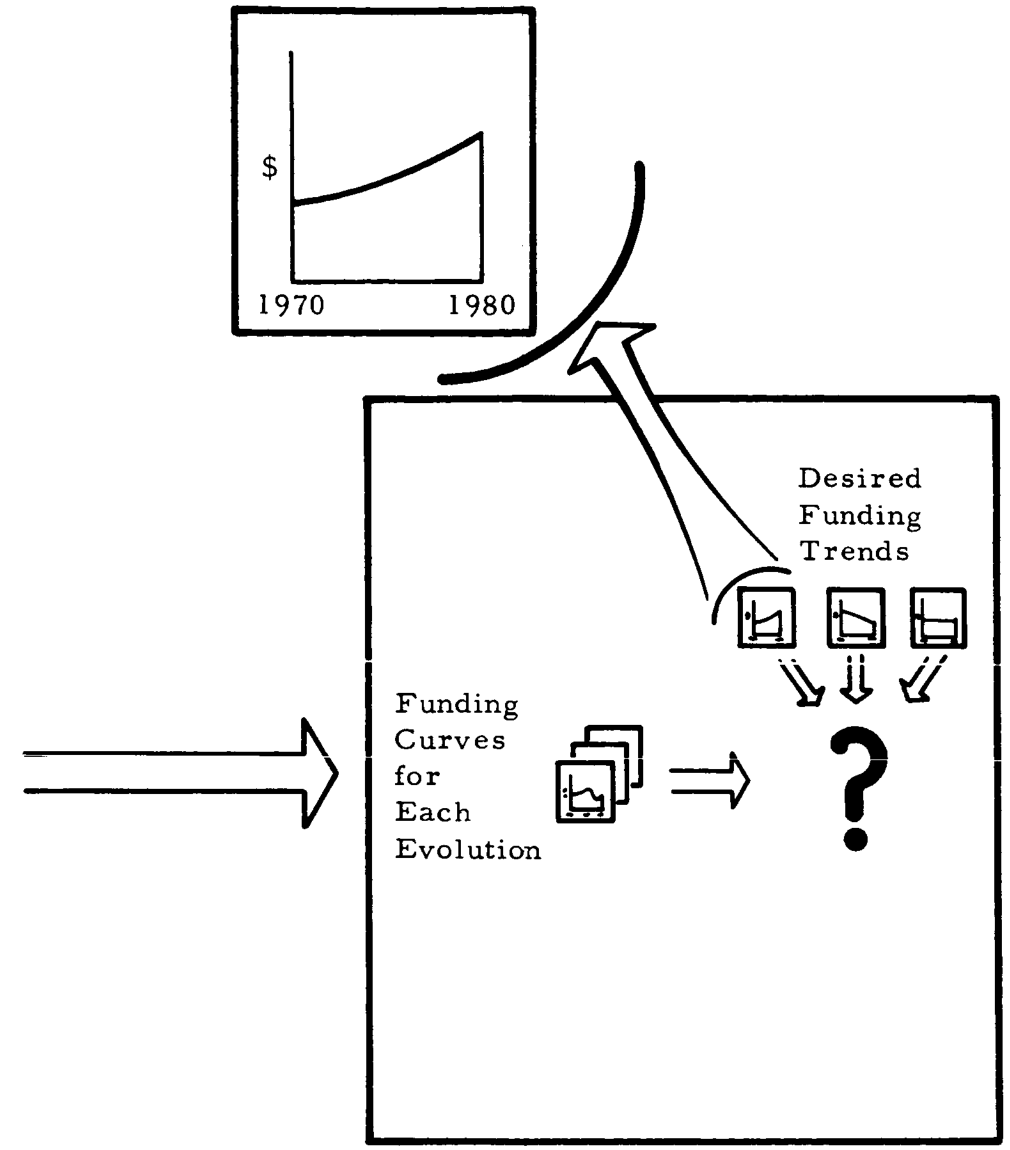


Figure 3-8 Funding Curve Trends

APPENDIX A

SYMBOLS USED IN LOGIC FLOW DIAGRAMS OF APPENDIX C

Symbol	Term
AM	Total mass of expendables for one leg (kg)
APM	Mass of an appendage (kg)
ΣAC	Total cost difference from all matrices (1966 $)
ΣAM	Total mass of expendables for all legs of a mission (kg)
ΣAPM	Total mass of all appendages required (kg)
C	Mobility expendables/sortie (kg)
C	Repeat article cost (1966 $)
CA	Crew mass (kg)
C_A	Actual cost of a development (1966 $)
CD	Crew difference
CLR	Cabin leak rate (kg/hr)
ΔC	Cost difference due to prior development (1966 $)
ΔC_T	Total cost difference from all matrices (1966 $)
D	Duration (days)
DFM	Delivered fueled mass (kg)

Symbol	Term
ΔD	Date vehicle is required minus present date (half years)
FC	Fuel consumed (kg)
FM	Fueled mass of a vehicle (kg)
g	Earth gravity (9.8 m/sec)
I_{sp}	Specific impulse of a flyer (sec)
K_A	Mobility expendables constant (kg/km/day)
LPC	Expendable mass loss per egress/ingress cycle (kg)
LSR	Life support expendables rate (kg/hr)
LT	Time to traverse a leg (hr)
m	Development cost increase factor due to deviation from nominal development time
M	Mission counter
MA	Mass of one astronaut (142.0 Kg)
MC	Mission crew size
MCM	Maximum crew mass (kg)
MD	Mission duration (hr)
M_f	Final mass of a flyer (kg)
M_i	Initial mass (kg)
M_{ii}	Initial mass (kg)
ML	Mobility mass limit for a mission (kg)

Symbol	Term
MM	Mass margin (kg)
MMC	Maximum value of MC x PM (kg)
MOM	Maximum operational mass (kg)
MPL	Mission payload (kg)
MRS	Maximum range from shelter (km)
N	Acceptable vehicle index
NT (M)	Mission vehicle counter
OM	Operational mass of a vehicle (kg)
PL	Payload (kg)
PM	PLSS mass (29.5 Kg)
Q_o	Ratio of actual development time to nominal development time
R	Range (km)
RL	Leg range (km)
RLS	Range of longest sortie (km)
ROL	Radius of operation limit (km)
SAM	Allocated expendable mass for sortie (kg)
SDT	Sortie driving time (hr)
SMM	Sortie mass margin (kg)
TAM	Total mass of all appendages required (kg)

Symbol	Term
TC	Total number of egress/ingress cycles
TDM	Total delivered mass (kg)
TFC	Total fuel consumed (kg)
TME	Total mass of an entry (kg)
TMV	Total mass of vehicles (kg)
TRD	Total rescue duration (hr)
TRM	Total range of a mission (km)
TST	Total sortie time (hr)
TT	Total time for all legs (hr)
t_f	Time of flight (hr)
t_o	Nominal development time (half years)
t_s	Development start date (half years)
$\bar{t}_o$	Modified development schedule (half years)
UM	Unfueled mass of a vehicle (kg)
V	Rover speed (km/hr)
VC	Vehicle maximum crew size
V_m	Rover maximum speed (km/hr)
V_u	Rover speed unmanned (km/hr)
ΔV	Change in velocity (M/sec)

Symbol	Term
ΔV_T	V required for all legs (M/sec)
W	Weight of a vehicle (kg)
W_1	Mobility mass expendables (kg)
W_2	Life support mass expendables (kg)
W_3	Expendable mass loss due to egress/ingress (kg)
W_E	Mass of expendables lost during lunar storage (kg)
W_o	Total expendable mass capacity of a vehicle (kg)
X_i	Ratio of expended costs in a half year to total development cost
Z_i	Ratio of committed costs in a half year to total development cost

APPENDIX B

GLOSSARY OF TERMS USED IN FLOW DIAGRAMS OF APPENDIX C

Adjunct Vehicle	A lunar mobility system which is transported piggyback by another mobility system for some distance prior to being put into operational use.
Allocated Mass	The expendable mass required by a vehicle to fulfill a specified mission.
Appendage	A piece of equipment used in conjunction with a prime mover or trailer for base support. Primarily these are soil moving devices such as backhoes or blades.
Base Support Mission	A mission whose function is to support operations of a lunar base or shelter by cargo and/or personnel transport, surface modification, etc.
Candidate Vehicle	A vehicle which the planner has specified for consideration with respect to a specific mission.
Cargo Capacity	The payload, soil, or other capacity of a base support vehicle expressed in kg.
Crew Mass	The mass of one or more crew members including his spacesuit and PLSS.
Development Time	The time required to develop a mobility system from development start to first flight article ready for launch.

Delivered Fueled Mass	The operational mass of a vehicle minus the crew mass if any.
Delivery System	A lunar lander such as LM, LM-Truck, Surveyor, etc.
ELMS 50-50	A lunar surface model used for traverses which are approximately half in the lunar maria and half in the highlands.
ELMS Highlands	A lunar surface model applicable to the lunar highlands.
ELMS Maria	A lunar surface model applicable to the lunar maria.
Entry	A prime mover or prime mover/trailer combination which satisfies a base support mission requirement.
Evolution	Same as set.
Expendables	Those items of equipment or supply which are mission dependent in quantity (fuel, batteries, tankage, payload, etc.).
Exploration Mission	A mission whose primary purpose is scientific exploration of the moon either by direct observation and data acquisition or by emplacement of automated instruments.
Fuel Mass	The mass of the liquid and gaseous expendables of a vehicle.
Fueled Mass	The unfueled mass of a vehicle plus a full store of propellants (applicable to flying vehicles only).
Half Year	A calendar half year such as 1973B (1 July 1973 to 21 December 1973).

Ingress-Egress Cycle	Entering and exiting a vehicle with cabin so that the cabin or airlock must be purged (depending upon whether the vehicle has an airlock or not) and recharged once.
Launch Date	The calendar half year during which a vehicle which fulfills a particular mission is to be launched.
Leg	A portion of a sortie.
Mass Limit	The constraint which specifies the maximum mass of a vehicle or vehicles for purposes of comparing the compatibility of this vehicle or vehicles with a delivery system.
Mass Margin	The mass of expendables that a vehicle is capable of carrying but are not required for the specified mission.
Maximum Operational Mass	The maximum mass at which a flyer is able to operate.
Mission	The specific task or objective of a single lunar surface transportation system.
Mission Class	Any of three functional categories of missions requiring mobility support: rescue, exploration, and base support.
Mission Crew Size	The specified crew size for a given mission.
Mission Duration	The elapsed time from when a vehicle departs from a shelter or base to embark upon a mission until the mission has been completed and the vehicle has returned to the shelter or base or has arrived at a designated position.

Mission Payload	The total mass of payload delivered to the lunar surface with a vehicle (as opposed to a lesser payload which may be employed on a specific sortie).
Nominal Development Time	The minimum cost development time for a mobility system assuming no prior developments.
Operational Mass	The unfueled mass of a vehicle plus the payload, crew, fuel, and any other expendables required to perform the mission.
Output Level	One of several categories of decision making data provided by the methodology.
Parent Vehicle	The lunar mobility system which transports an adjunct vehicle.
Payload	That equipment to be transported by a vehicle in addition to the normal functional elements of the vehicle exclusive of the crew, their spacesuits and PLSS.
Prime Mover	A self-powered and self-controlled base support vehicle.
Radius of Operation	Radius from a base or shelter to which a vehicle's operation is limited due to line of sight or other constraint.
Remote Control	Control of a vehicle from a remote location (earth or other) by reception and display of necessary video and other data from the vehicle and transmission of proper control commands.
Rescue Mission	Those missions which provide assistance to a crew member or members in unplanned situations where supplies or transportation are required.

Set	A group of vehicles which contains one vehicle for every mission of a specified program with a one-to-one correspondence between vehicles and missions. Also called an evolution.
Sortie	A travel which commences and terminates at a shelter or base (not necessarily the same one), but which constitutes only a portion of a mission.
Start-Date	The calendar half year during which development of a vehicle is to commence.
Storage Time	The time, expressed in months, which a vehicle remains unused on the lunar surface between lunar landing and mission start.
Unfueled Mass	The mass of a vehicle without expendables or crew.
Vehicle Class	General function for which a vehicle is designed (exploration, base support, rescue).
Vehicle Crew Size	The maximum crew that a vehicle is able to accommodate.

APPENDIX C

LOGIC FLOW DIAGRAMS

Note: Detailed explanation of these flow charts is contained in Volume II, Book 6.

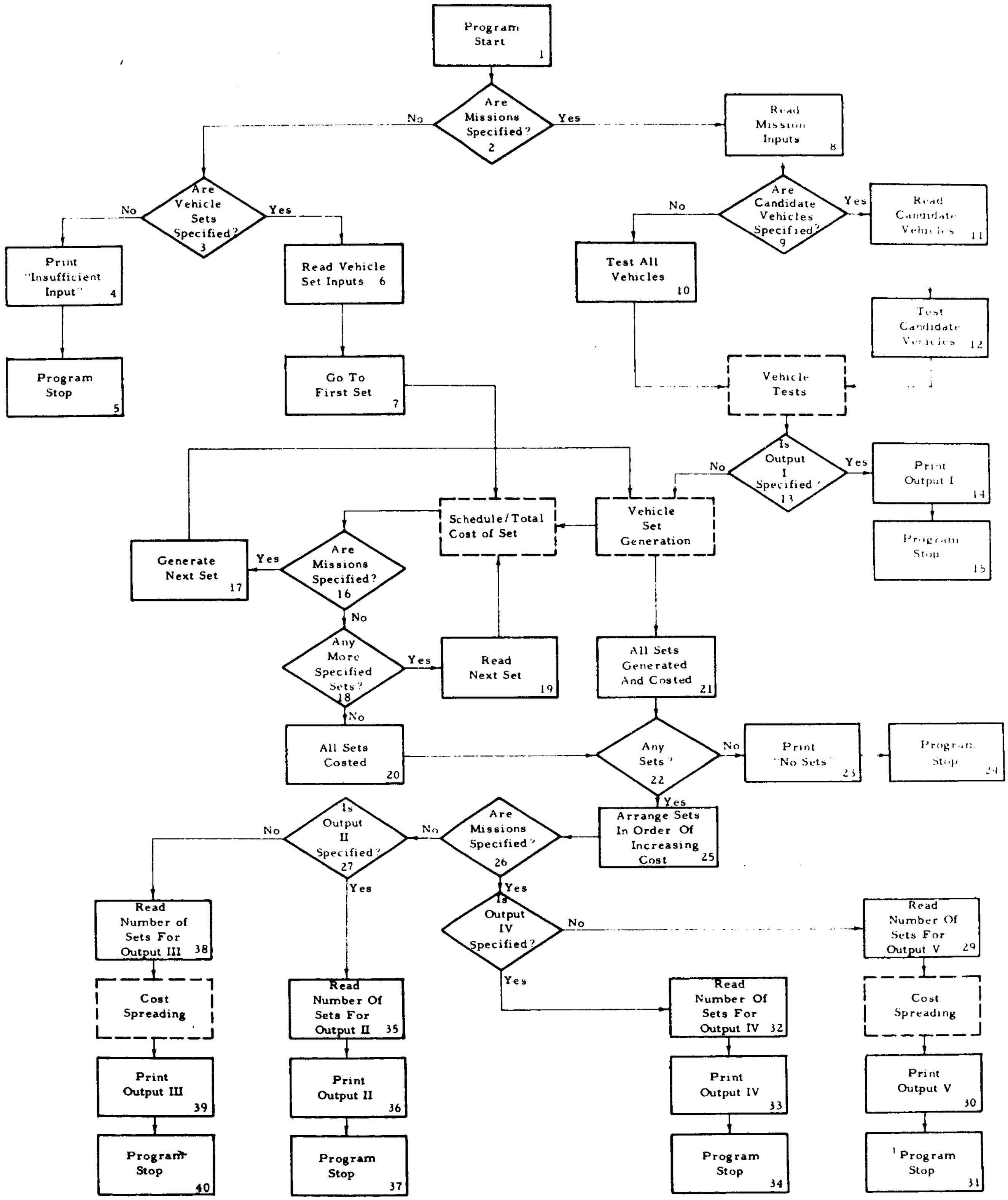


Figure C-1 Overall Program Logic

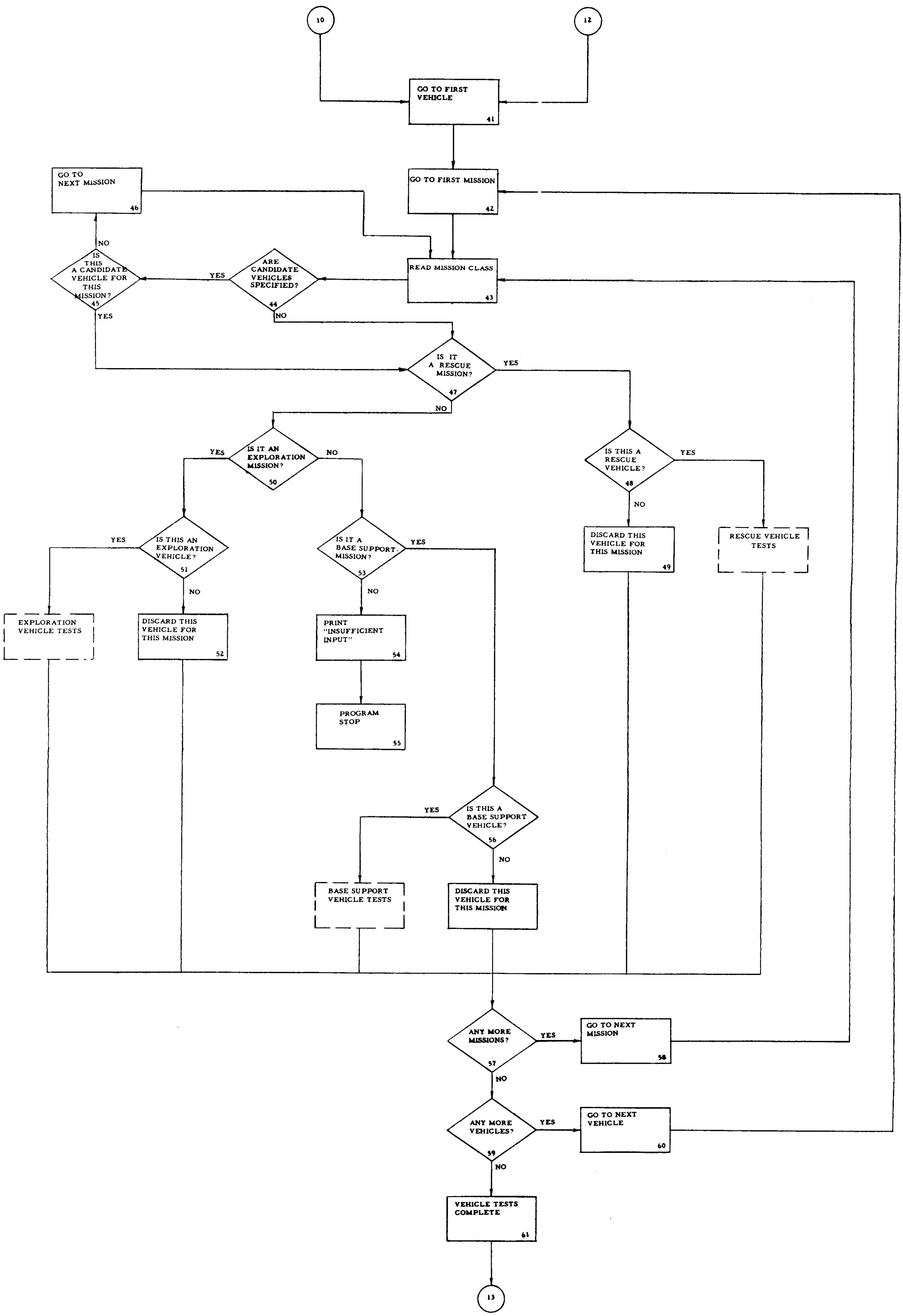


Figure C-2 Vehicle Tests

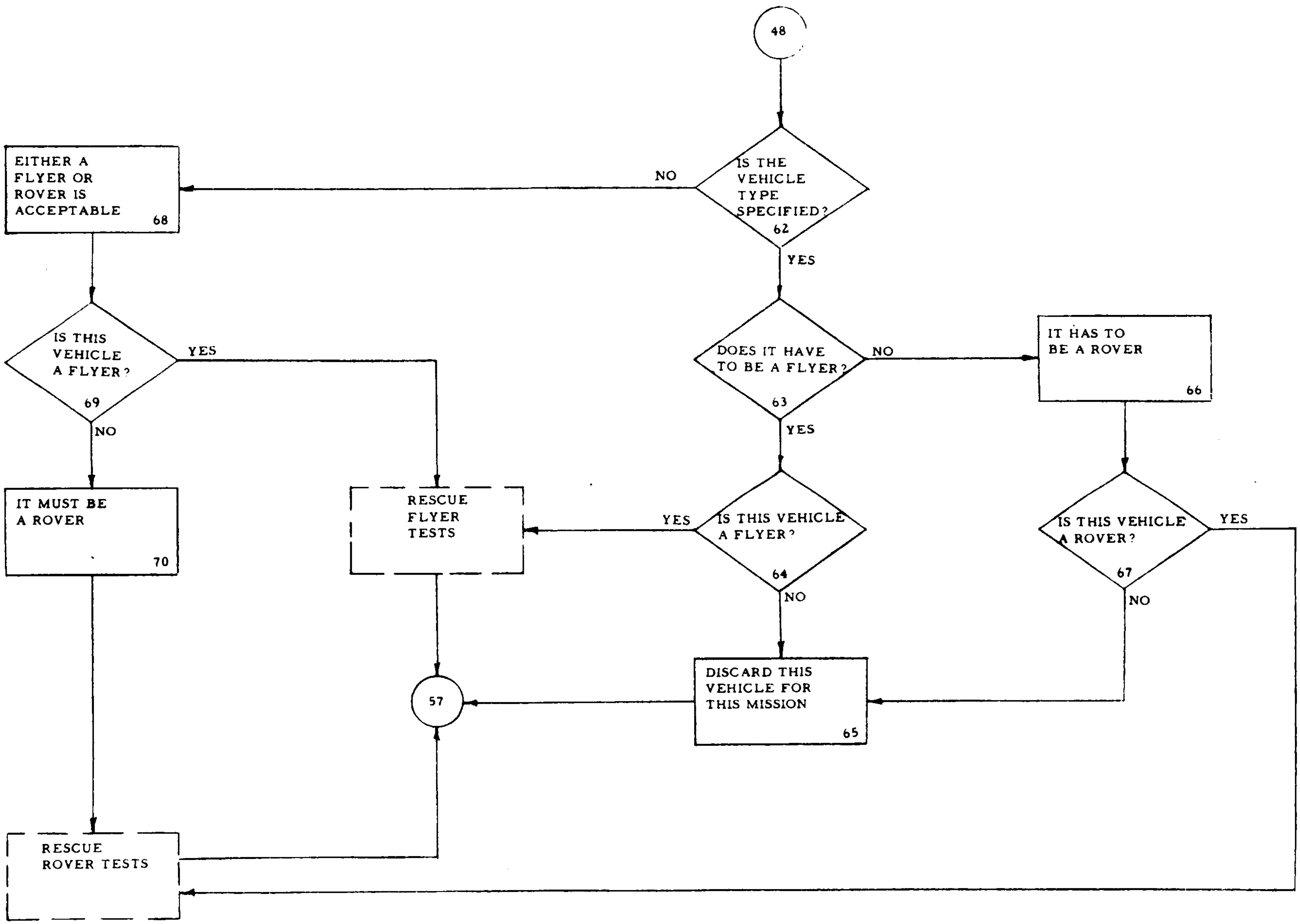


Figure C-3 Rescue Vehicle Tests

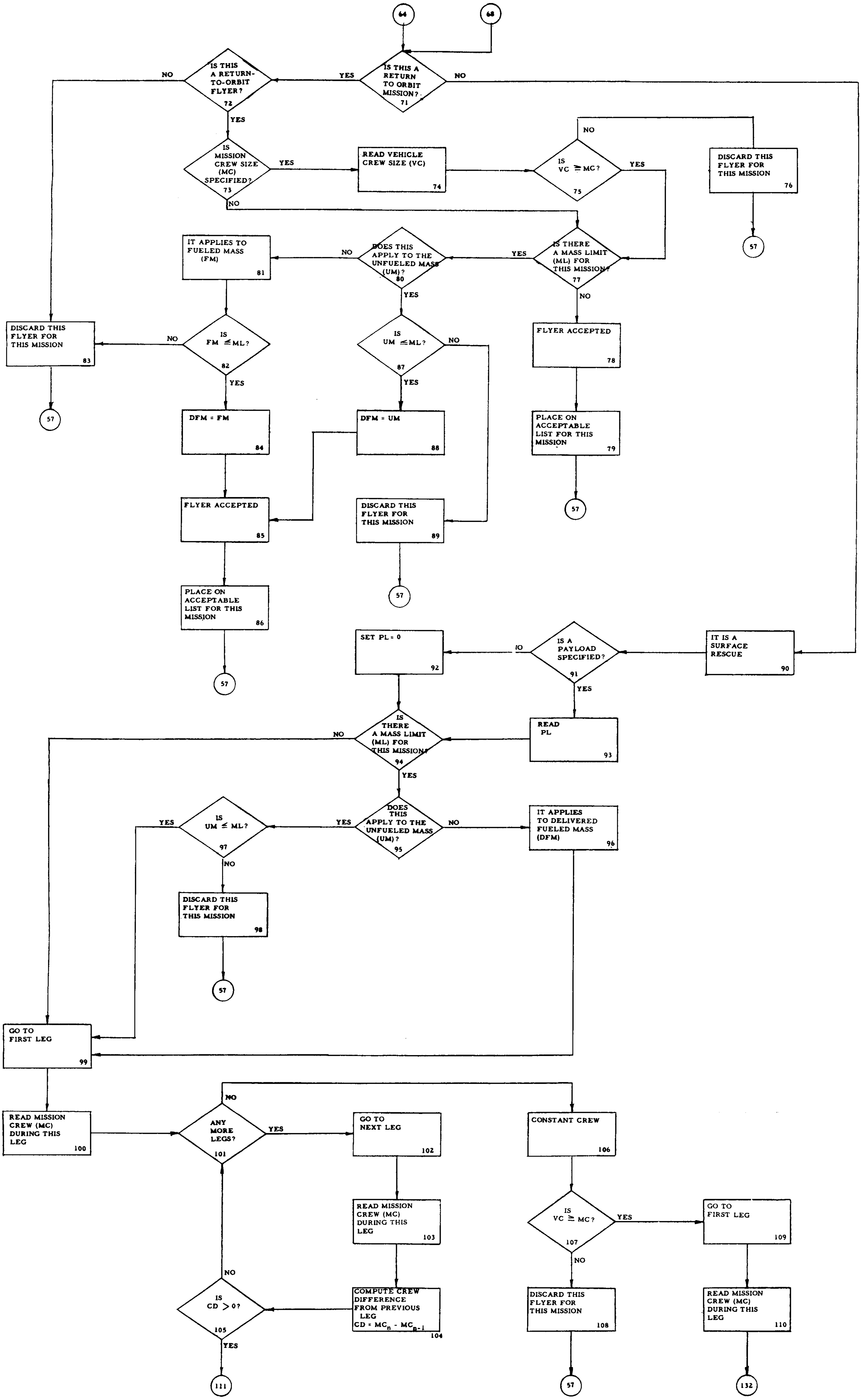


Figure C-4 Rescue Flyer Tests (Sheet 1 of 2)

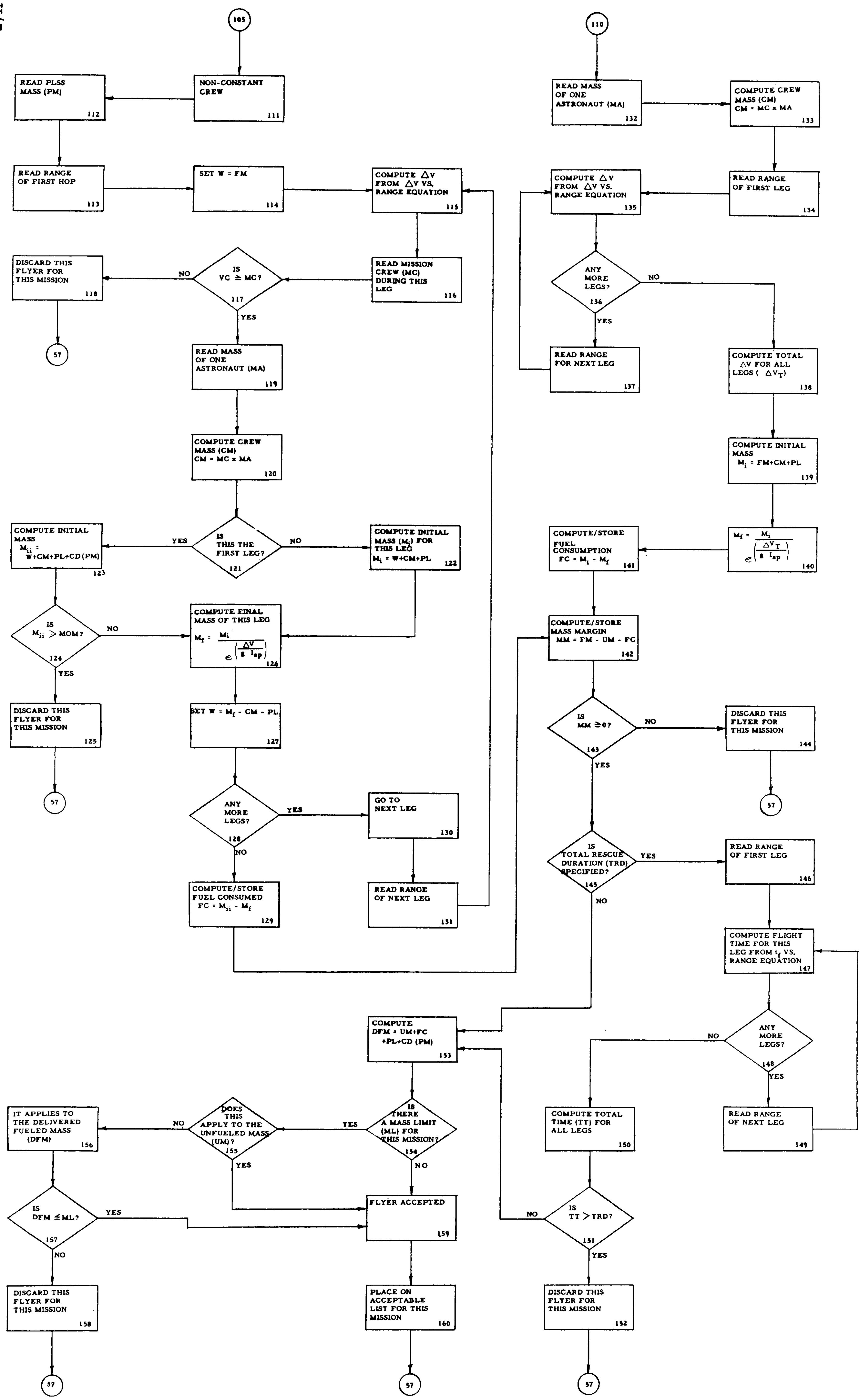


Figure C-4 Rescue Flyer Tests (Sheet 2 of 2)

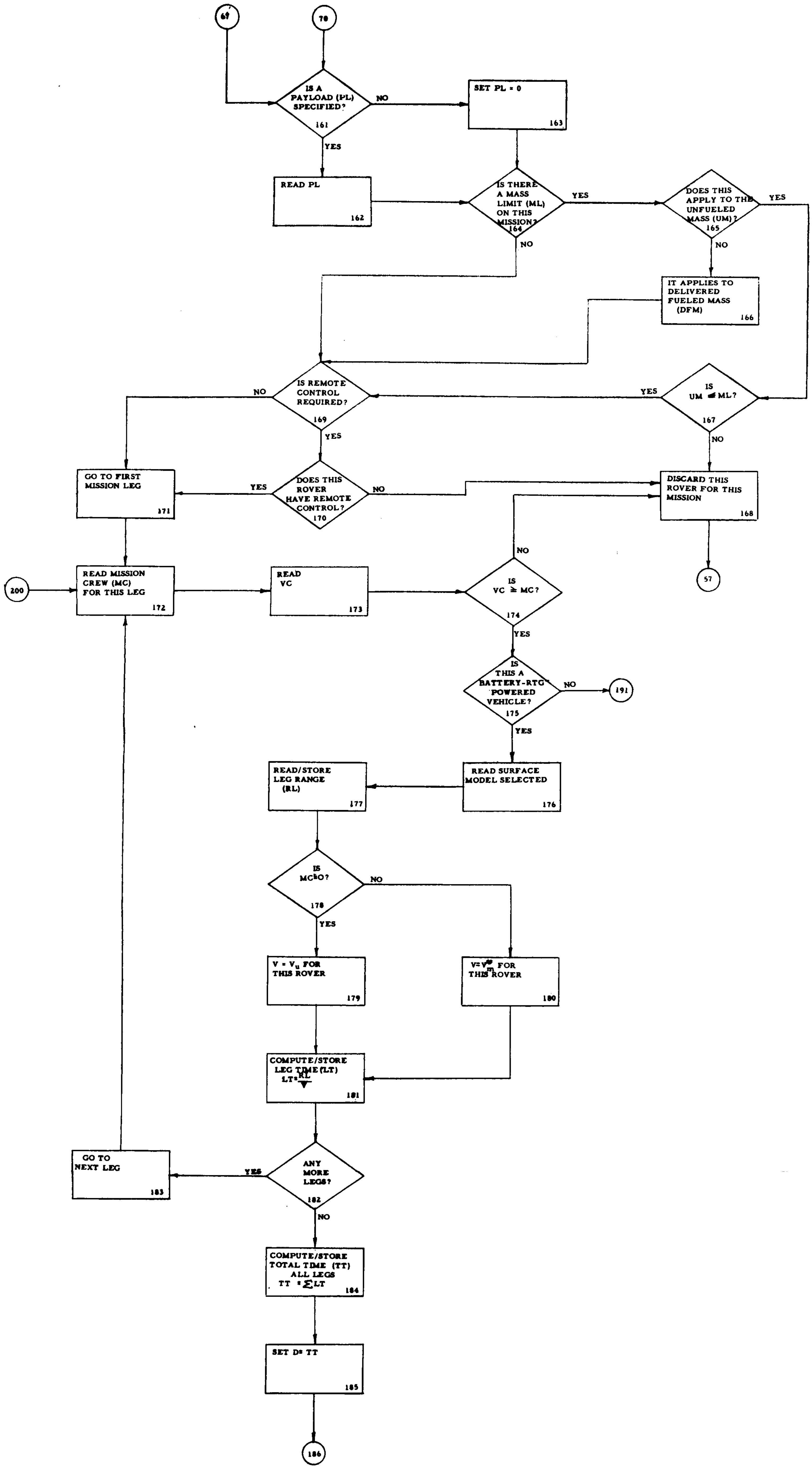


Figure C-5 Rescue Rover Tests (Sheet 1 of 3)

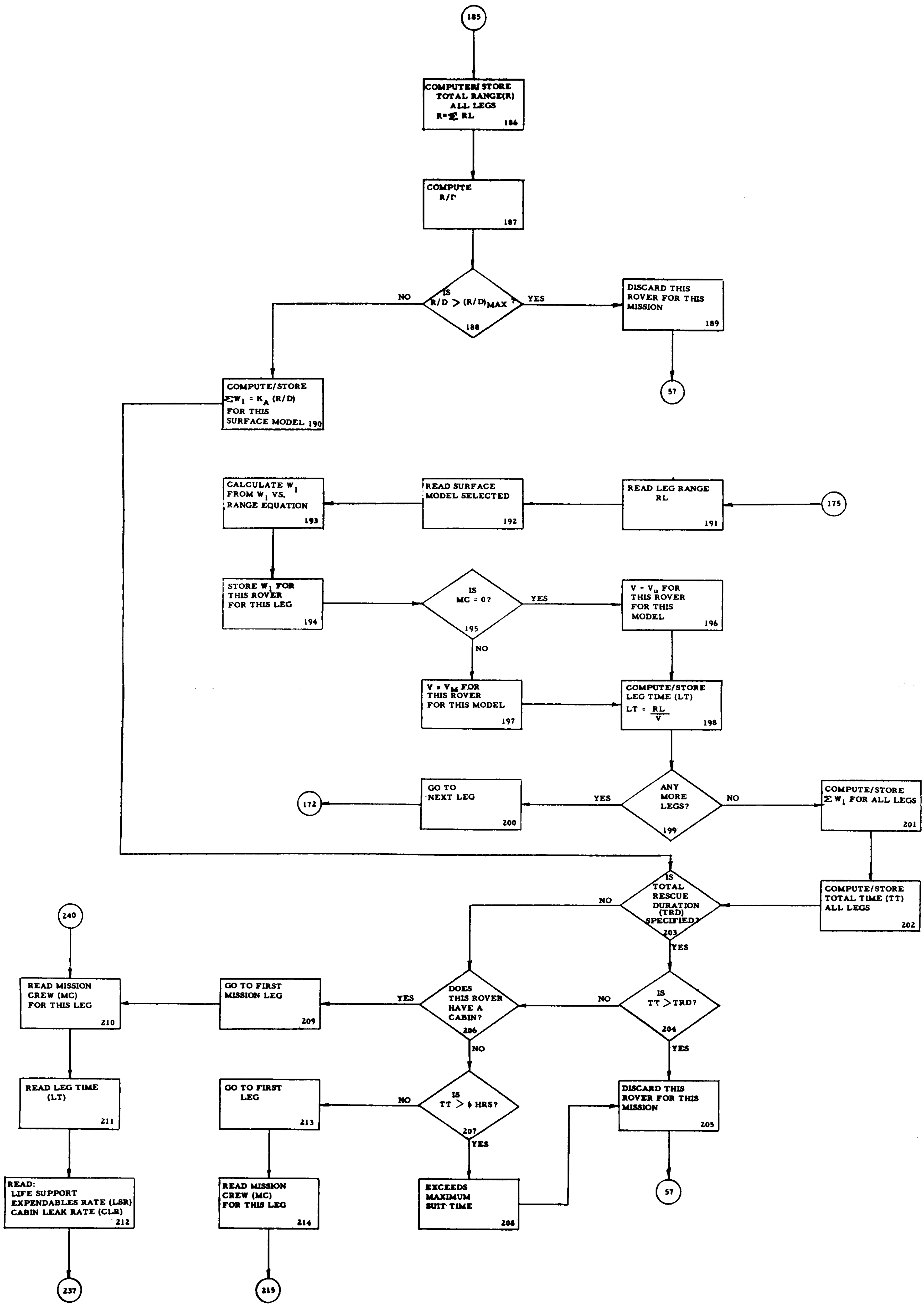


Figure C-5 Rescue Rover Tests (Sheet 2 of 3)

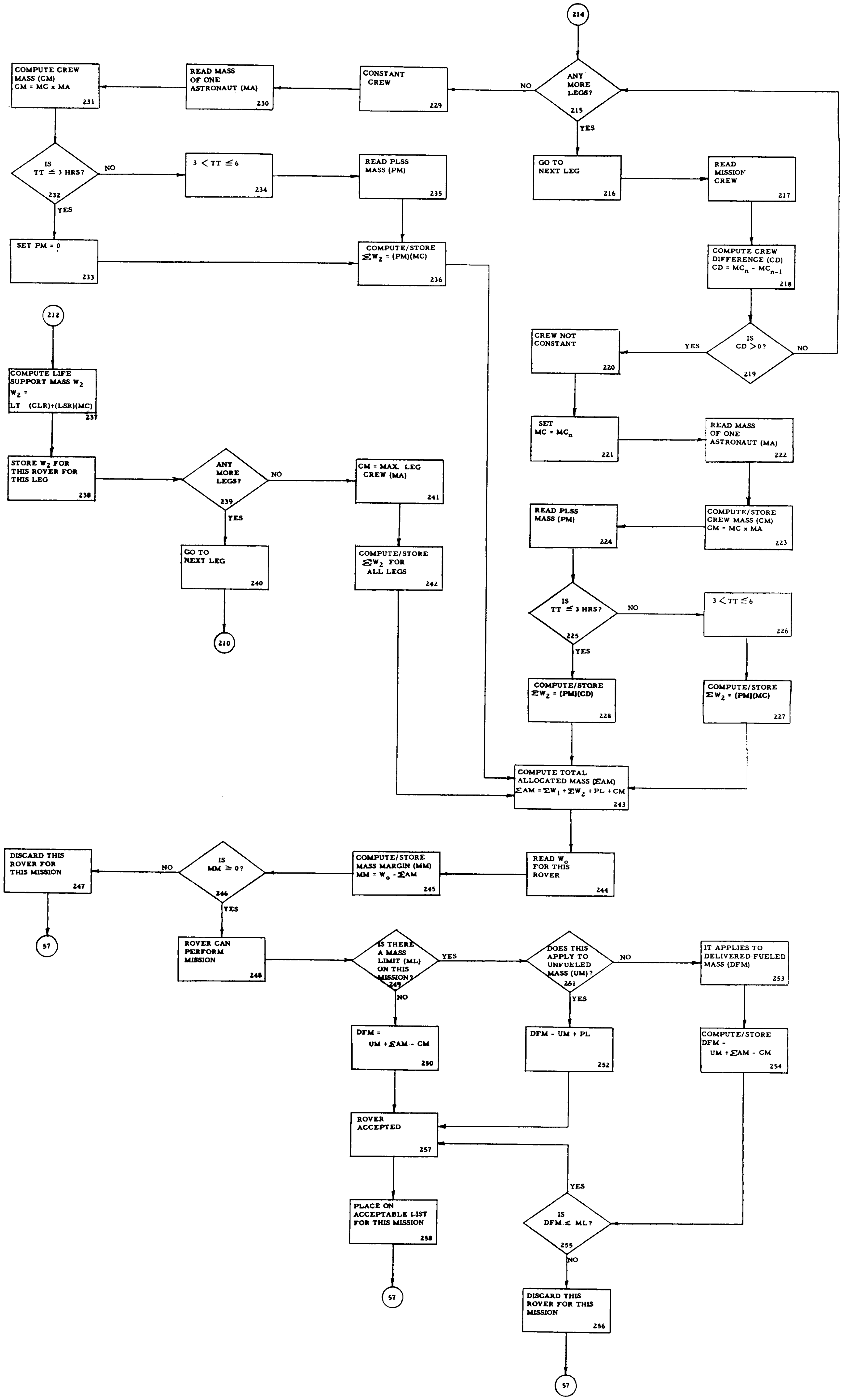


Figure C-5 Rescue Rover Tests (Sheet 3 of 3)

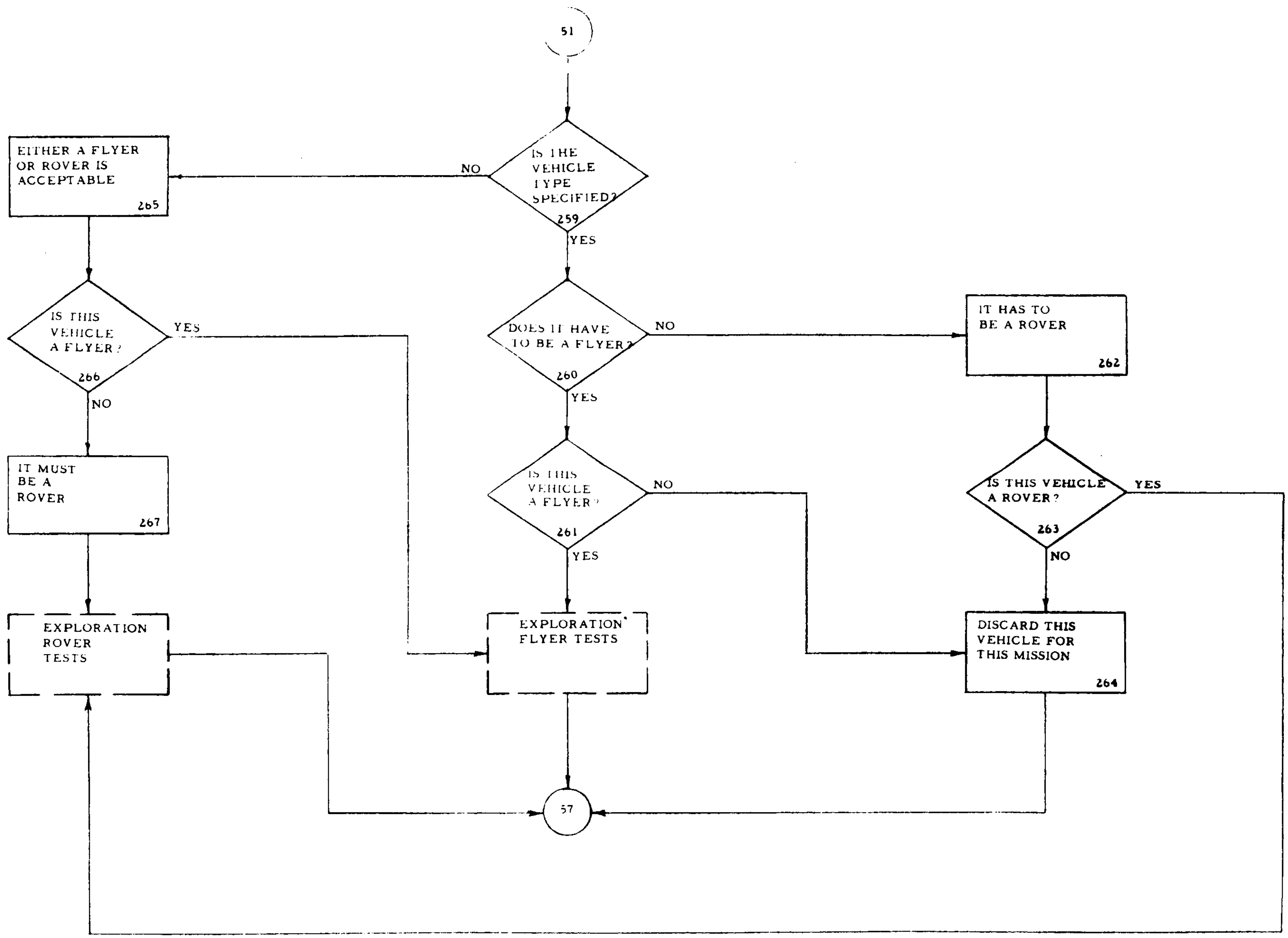


Figure C-6 Exploration Vehicle Tests

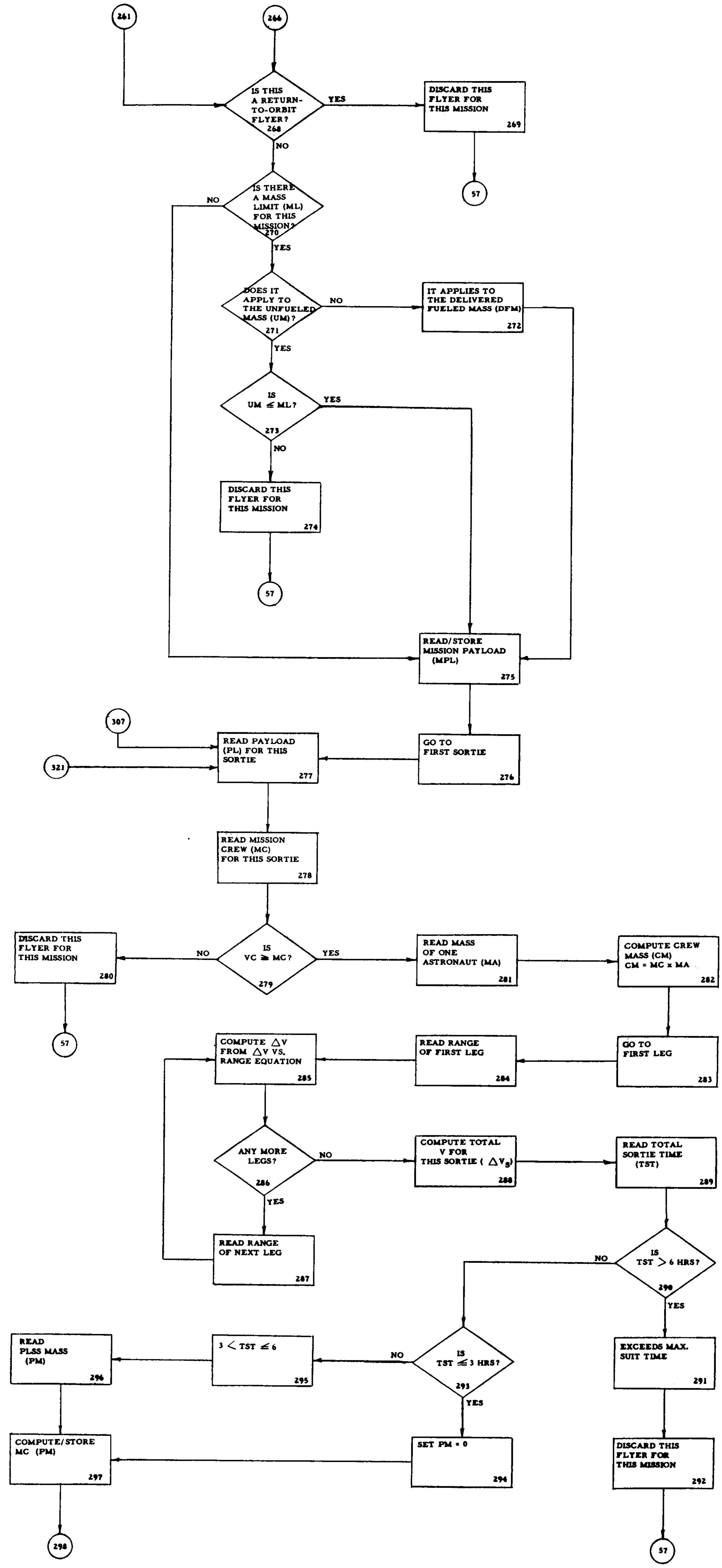


Figure C-7 Exploration Flyer Tests (Sheet 1 of 2)

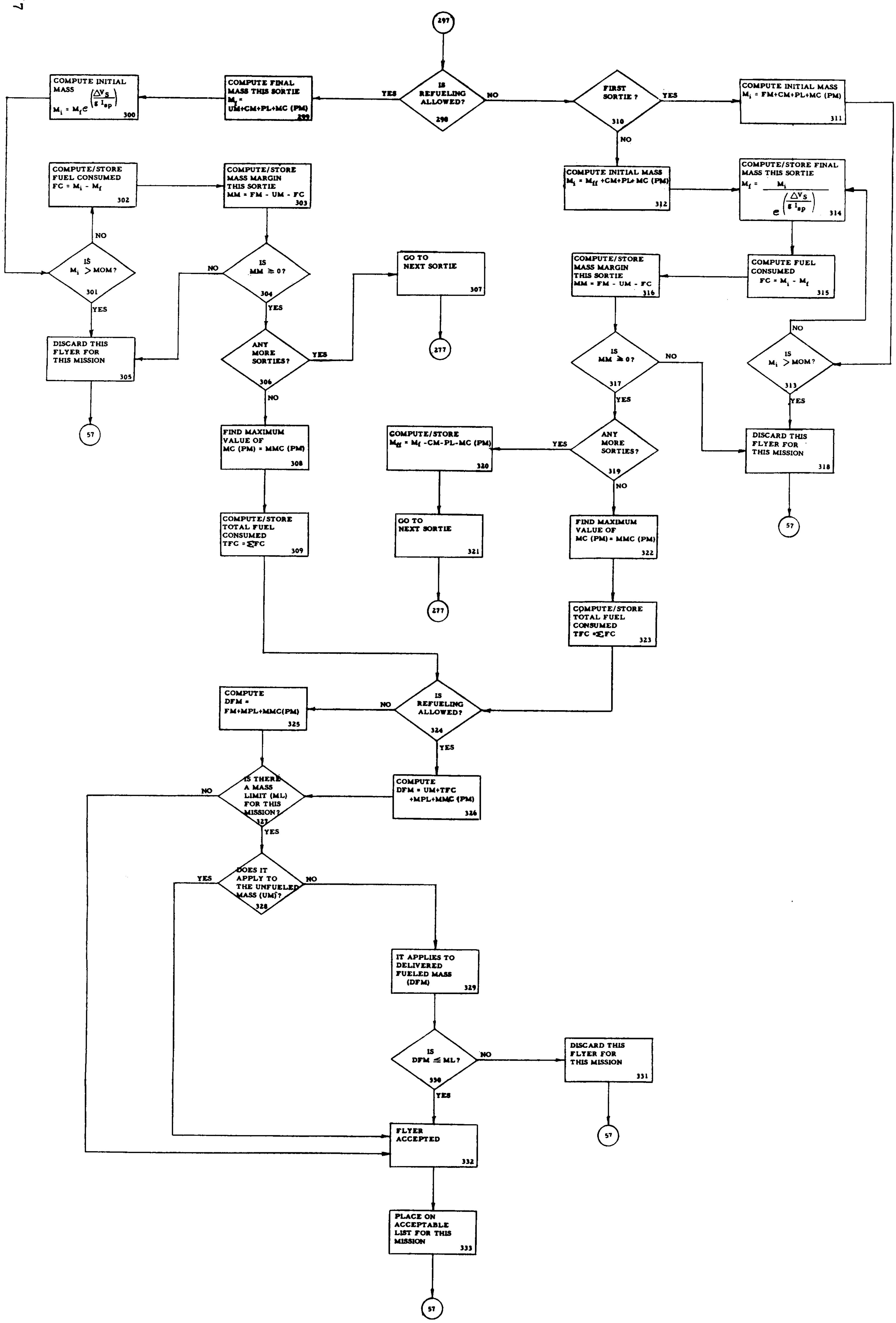


Figure C-7 Exploration Flyer Tests (Sheet 2 of 2)

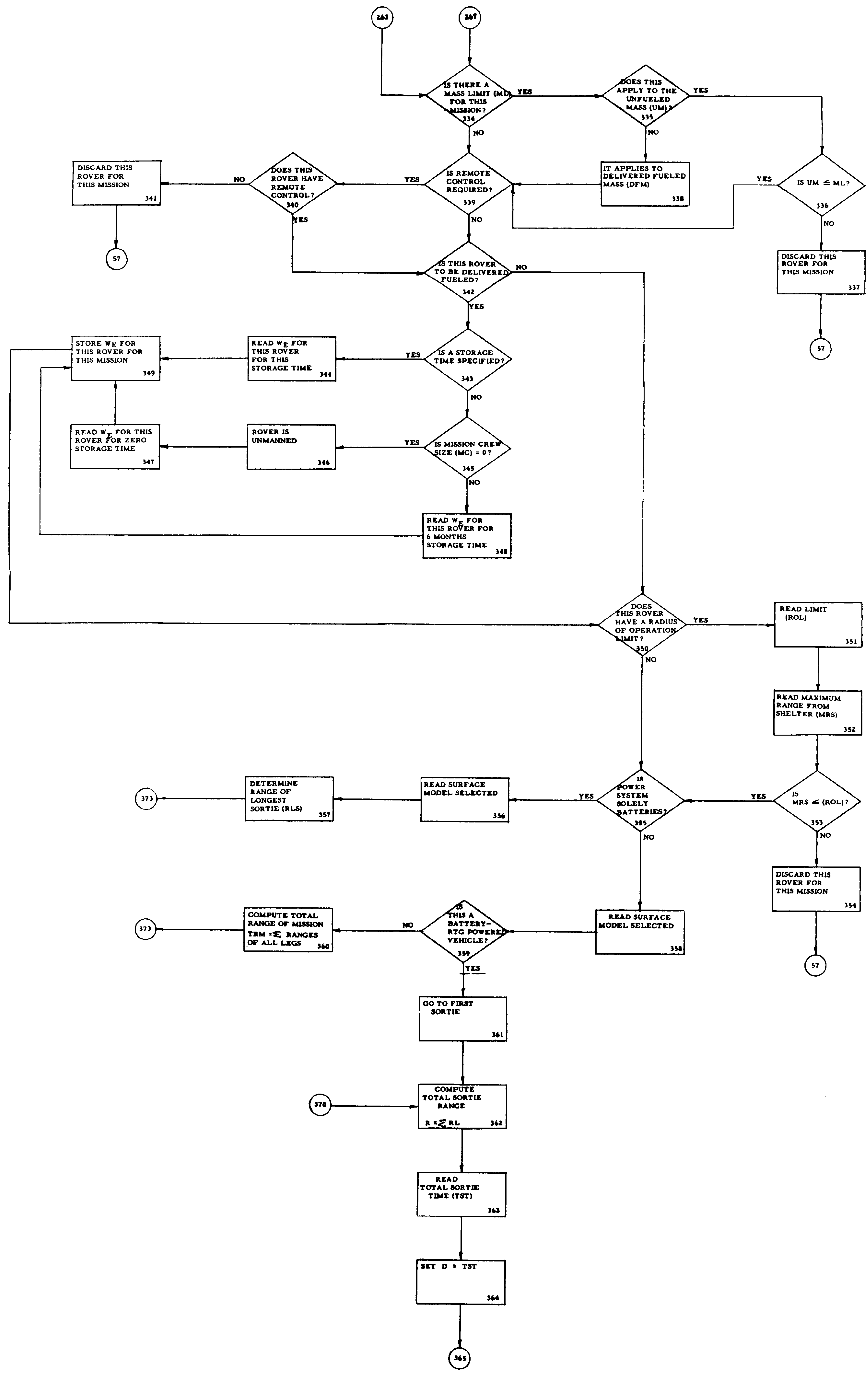


Figure C-8 Exploration Rover Tests (Sheet 1 of 4)

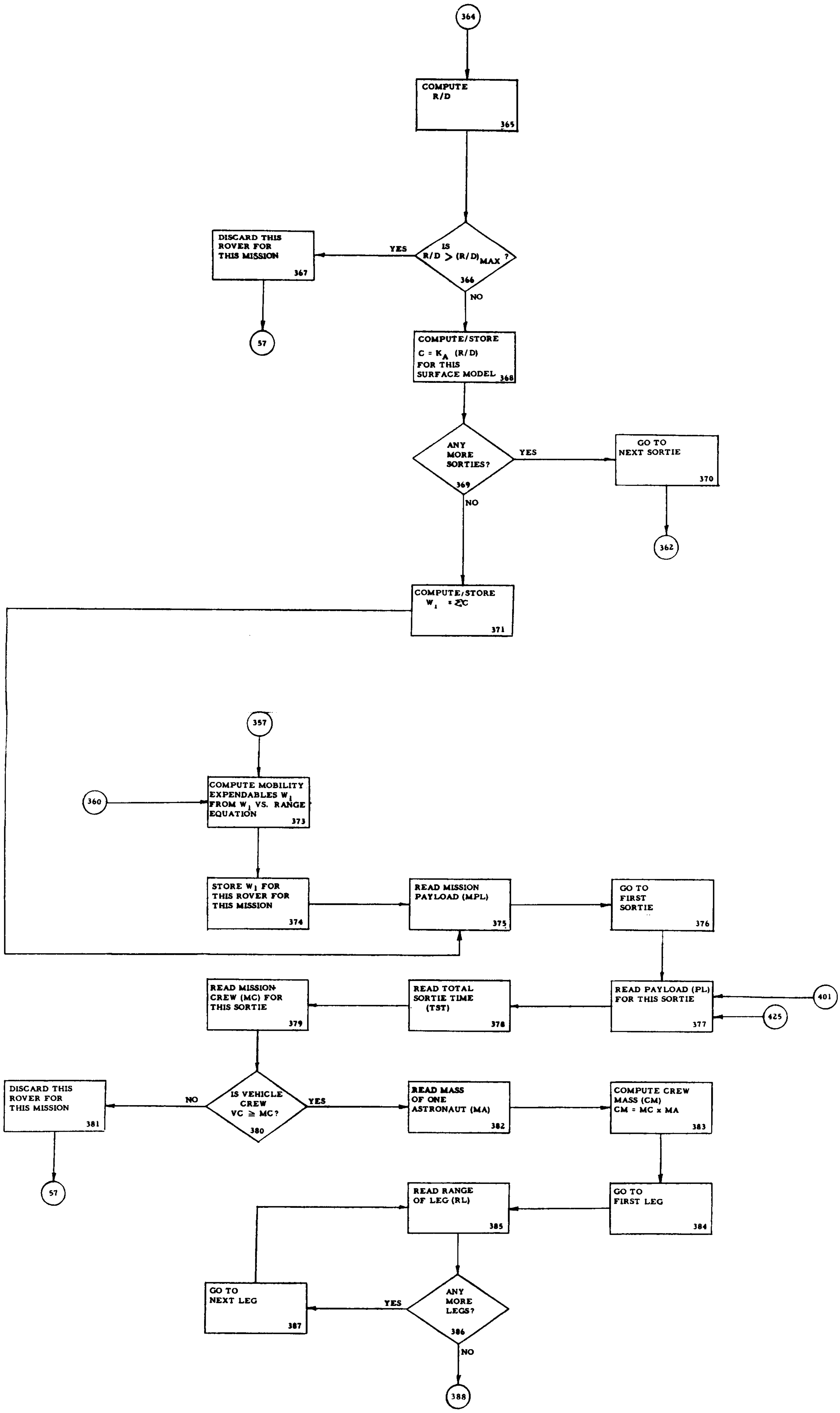


Figure C-8 Exploration Rover Tests (Sheet 2 of 4)

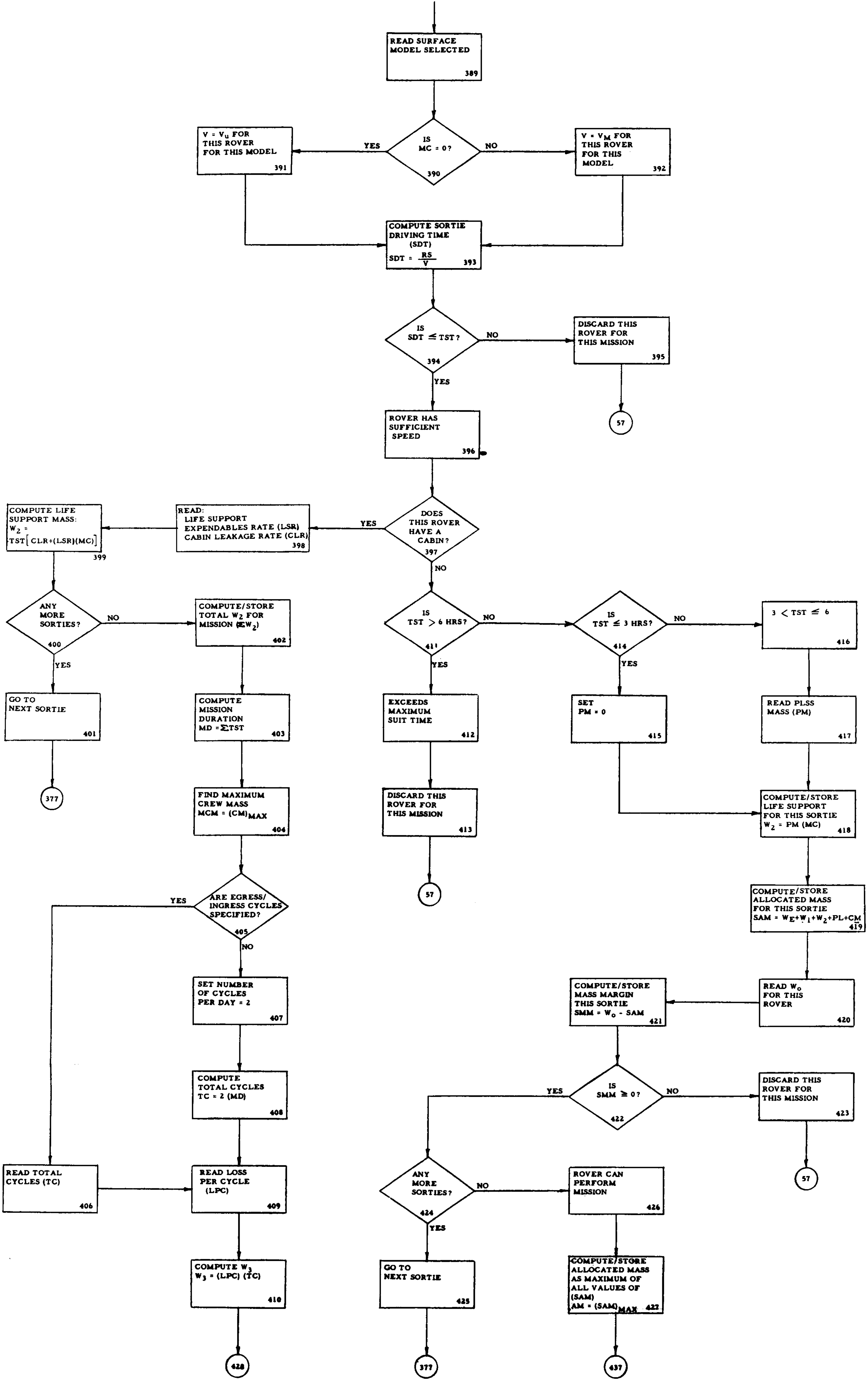


Figure C-8 Exploration Rover Tests (Sheet 3 of 4)

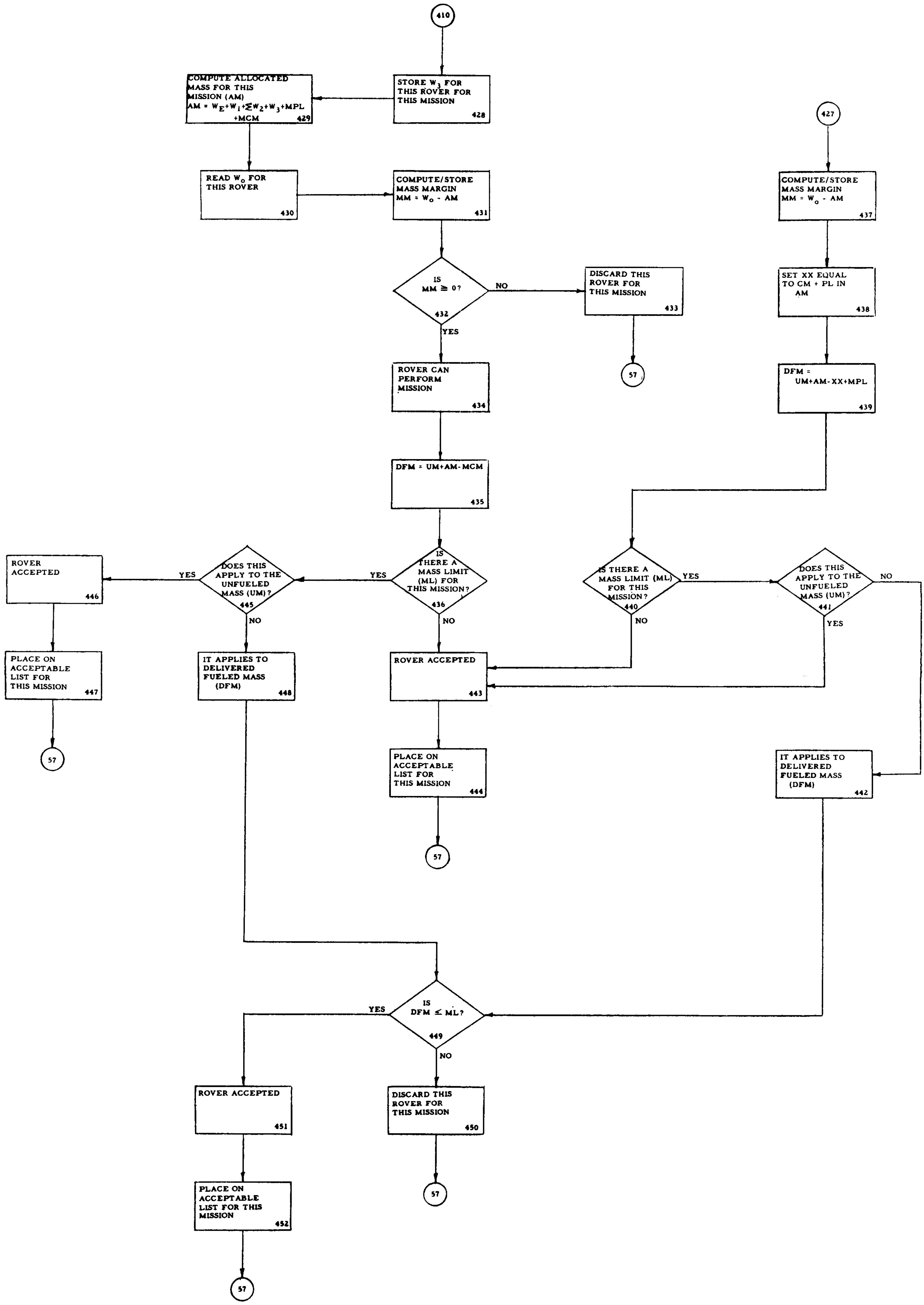


Figure C-8 Exploration Rover Tests (Sheet 4 of 4)

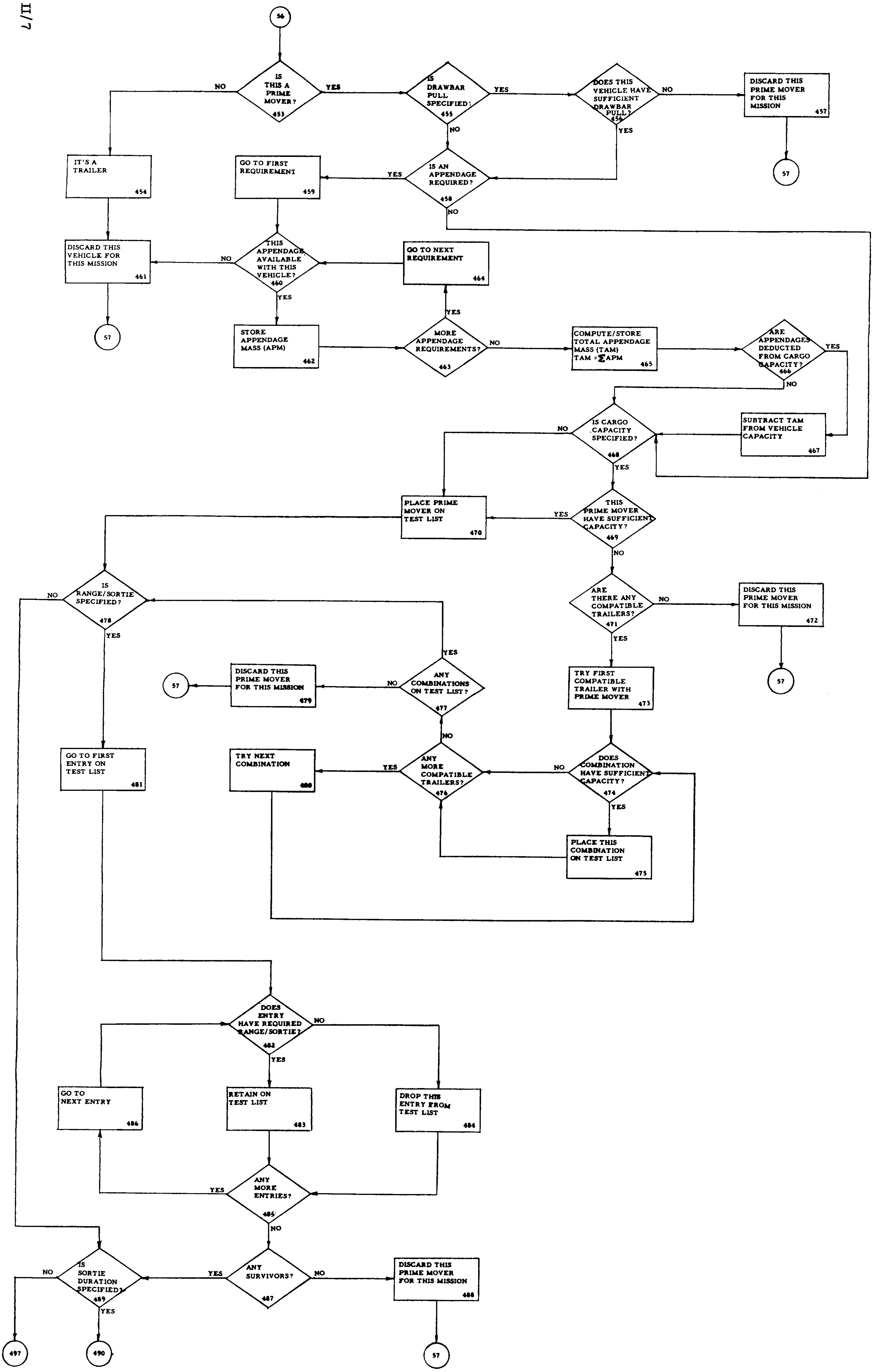


Figure C-9 Base Support Vehicle Tests (Sheet 1 of 2)

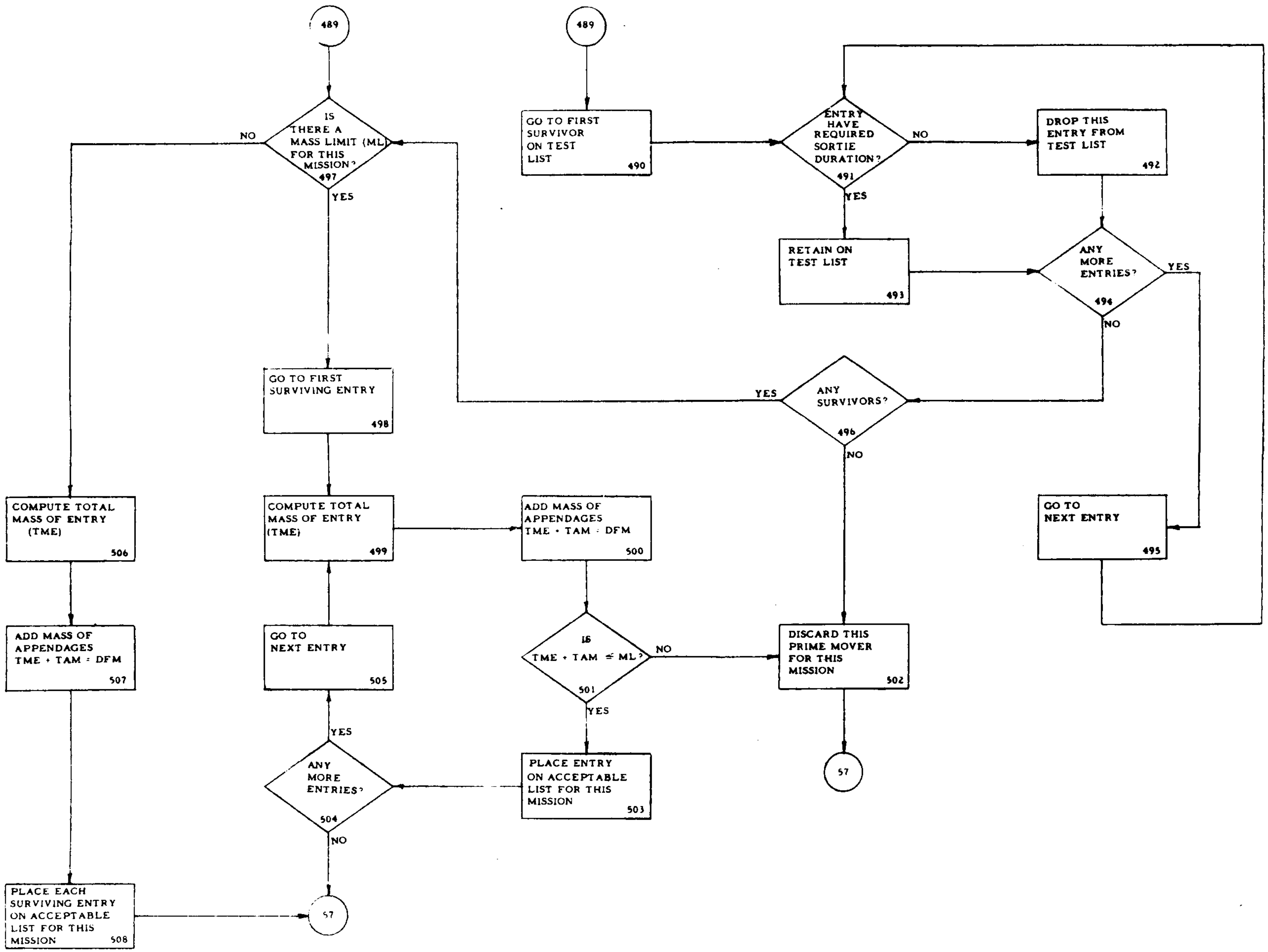


Figure C-9 Base Support Vehicle Tests (Sheet 2 of 2)

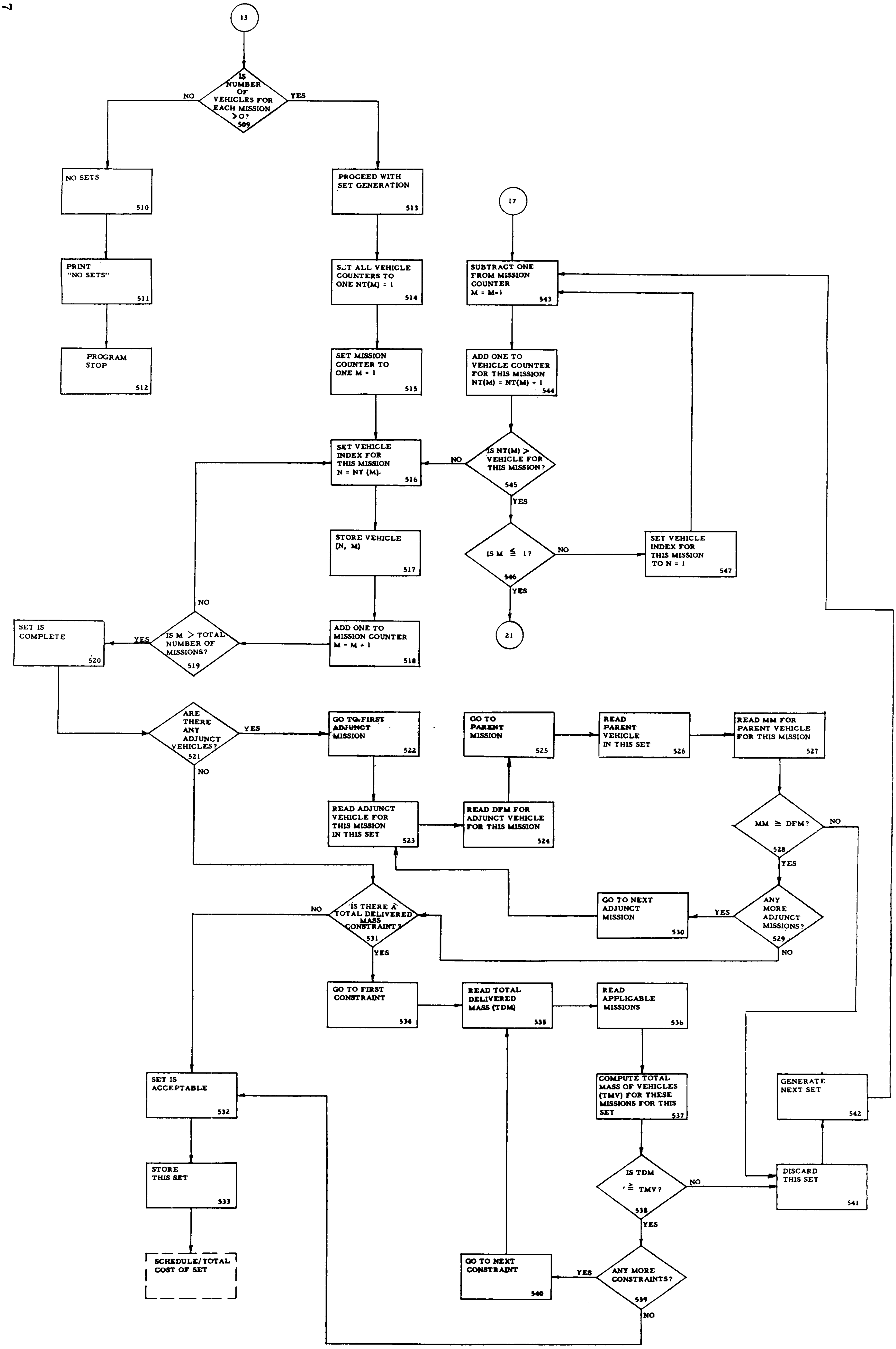


Figure C-10 Vehicle Set Generation

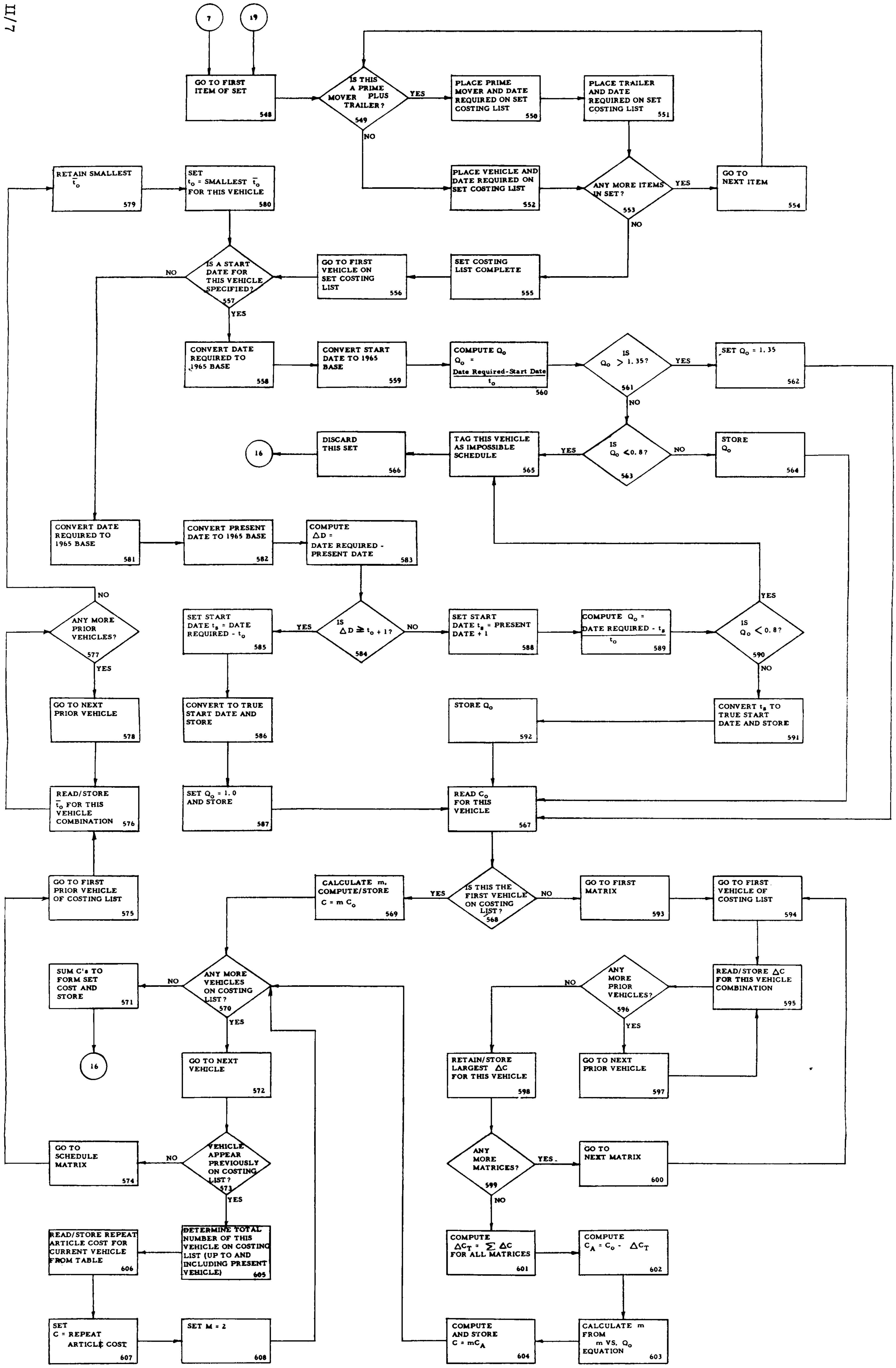


Figure C-11 Schedule/Total Cost of Set

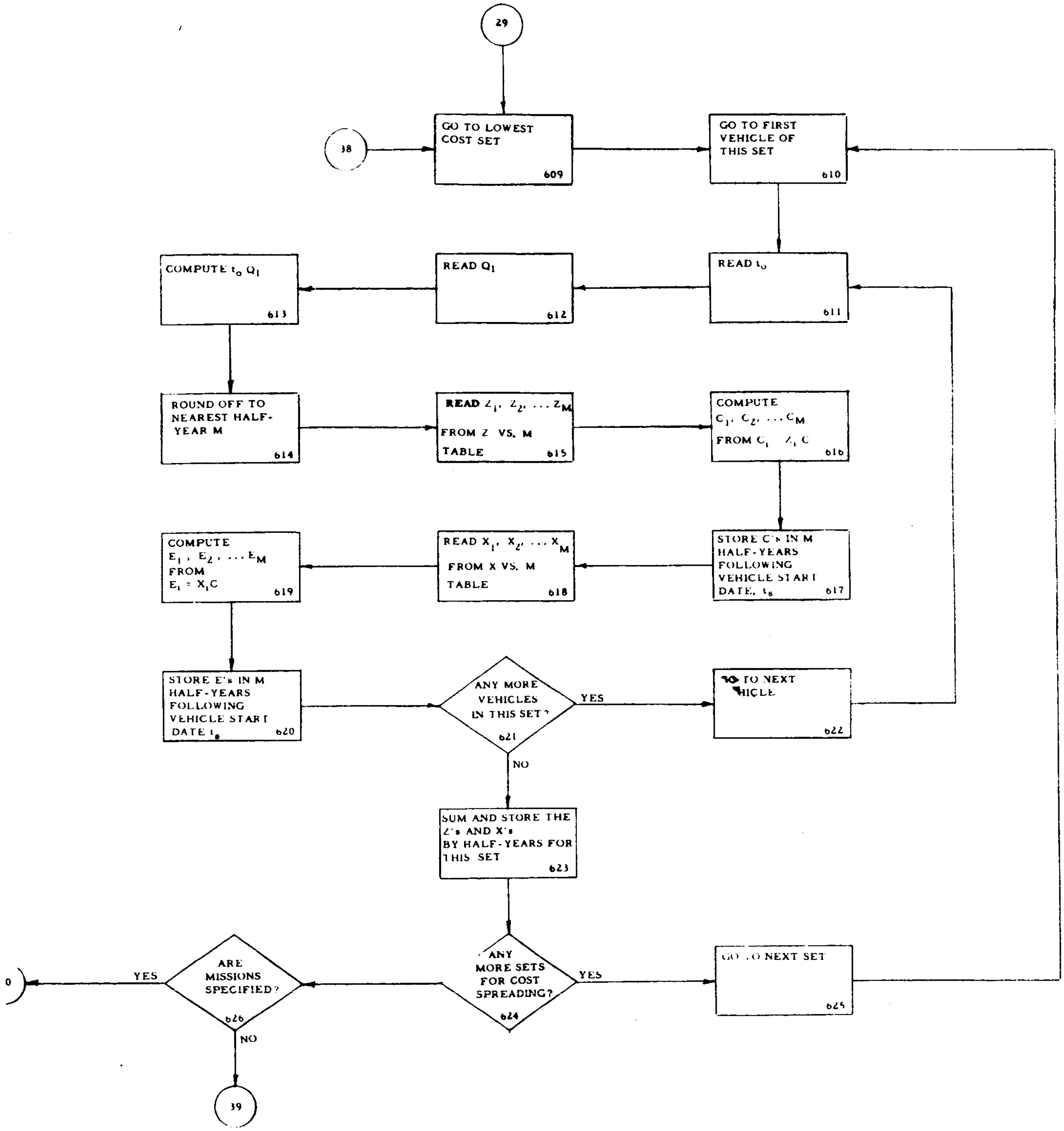


Figure C-12 Cost Spreading

APPENDIX D

VEHICLE PERFORMANCE DATA USED IN COMPUTER PROGRAM

This appendix summarizes the technical data stored on tape for use in the Methodology Computer Program. Flyer data are discussed first, followed by Rover and base support vehicle data in that order. It should be emphasized that provisions have been made in the computer program to accommodate 50 vehicles.

D. 1 FLYER DATA

Table D-1 contains the Flyer data for the 13 Flyers in the library. More detailed data on each Flyer are found in Vol III. Table D-1 can be discussed most easily by referring to the item numbers shown at the left.

1. Vehicle Number - This is the index number assigned to the vehicle within the computer. Flyers are listed first, followed by Rovers, then base support vehicles.

3. Class - Refers to whether the Flyer is applicable to exploration, rescue, or base support operation. All Flyers, with the exception of those with return-to-orbit capability, are capable of rescue and exploration missions. The return-to-orbit vehicles are classed as rescue vehicles only.

5. Fueled Mass - Same as delivered fueled mass as defined in the glossary. The sum of inert plus propellants.

6. Unfueled Mass - Fueled mass minus usable propellant.

10. Maximum Operational Mass - For surface Flyers, this is taken as 1.25 times the gross mass where gross mass is the sum of fueled mass, crew, and payload. For return-to-orbit Flyers, the maximum operational mass equals the gross mass. Also, for return-to-orbit Flyers both fueled and unfueled masses include the launch pad mass.

TABLE D-1

FLYER TECHNICAL DATA

Item													
1. VEHICLE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13
2. CODE NAME	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
3. CLASS:													
E = EXPLORATION R = RESCUE B = BASE SUPPORT	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R
4. VEHICLE TYPE	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer	Flyer
5. FUELED MASS (KG)	64.1	82.0	309.9	287.9	391.8	530.5	788.3	1106.5	529.1	1074.5	2066.5	4209.4	1476.5
6. UNFUELED MASS (KG)	32.8	35.3	114.4	172.2	205.8	242.2	298.4	338.9	268.3	394.1	615.0	1034.4	449.4
7. RETURN-TO-ORBIT CAPABILITY	No	No	No	No	No	No	No	Yes	No	No	No	No	Yes
8. MAXIMUM VEHICLE CREW SIZE	1	1	1	2	2	2	2	2	3	3	3	3	3
9. SPECIFIC IMPULSE (SEC)	290	290	290	290	290	290	290	290	290	290	290	290	290
10. MAXIMUM OPERATIONAL MASS (KG)	258.0	279.2	564.4	714.9	844.3	1018.1	1340.3	1364.5	1195.0	1875.6	3115.6	5790.0	1864.5
11. Δ V VS. RANGE													
$\Delta V = K_4 R^{(K_5)}$													
K_4	168	168	139	154	139	128	128	-	139	128	128	123	-
K_5	0.484	0.484	0.484	0.484	0.484	0.484	0.484	-	0.484	0.484	0.484	0.484	-
12. FLIGHT TIME VS. RANGE													
$t_f = K_7 R^{(K_8)}$													
K_7	0.0226	0.0226	0.0226	0.2095	0.2095	0.2095	0.2095	-	0.2095	0.2095	0.2095	0.2095	-
K_8	0.4025	0.4025	0.4025	0.134	0.134	0.134	0.134	-	0.134	0.134	0.134	0.134	-

11. ΔV versus Range - This relationship varies with the guidance system aboard the Flyer. Figure D-1 shows a plot of these variations with the guidance system assignments.

12. Flight Time versus Range - The time of flight relationships, plotted in Figure D-2 include allowances of 36 seconds warmup for 1-man vehicles, and 900 seconds warmup for multiman vehicles.

In addition, it is assumed that all Flyers have refuel capability.

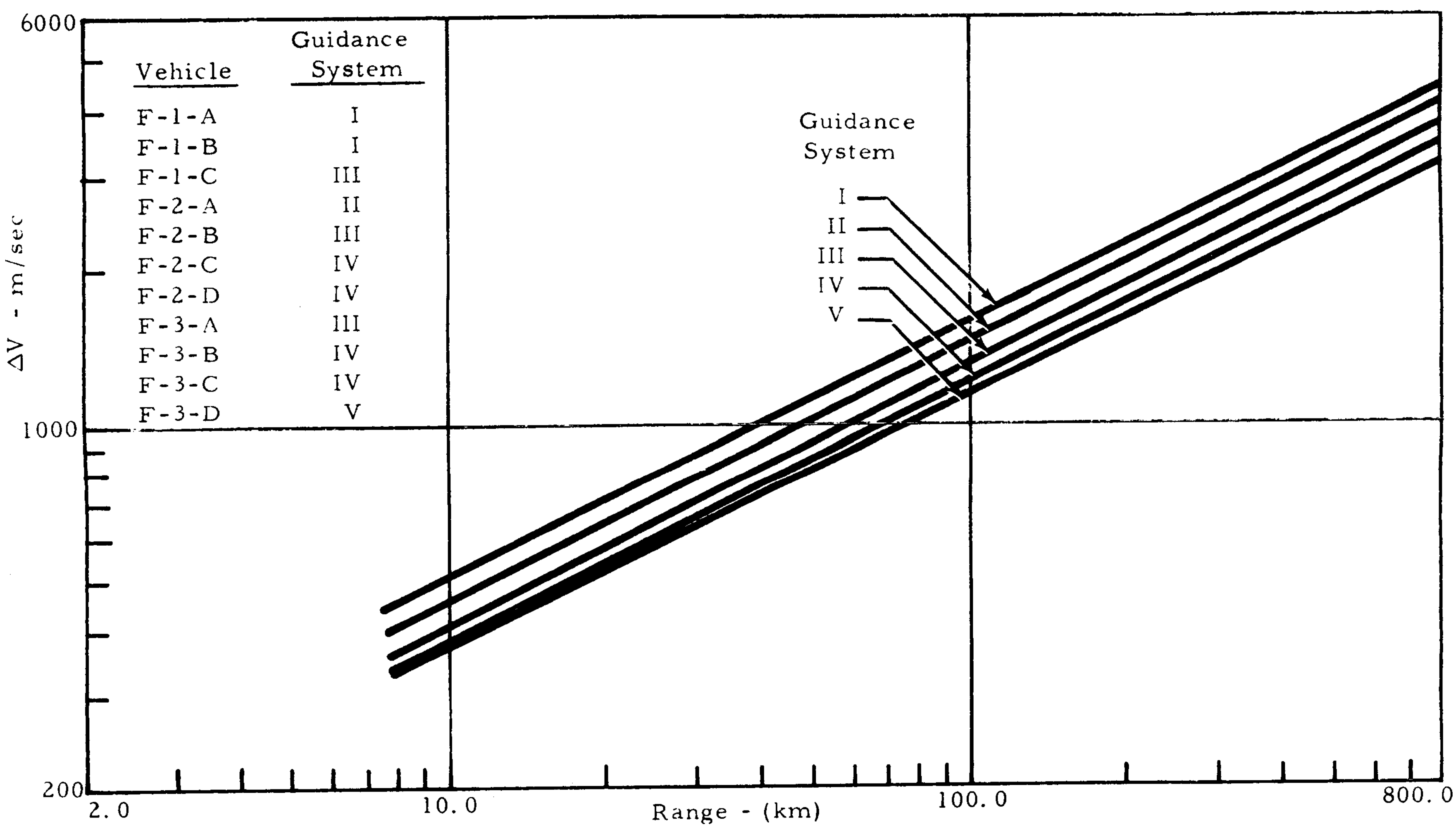


Figure D-1 ΔV vs Range

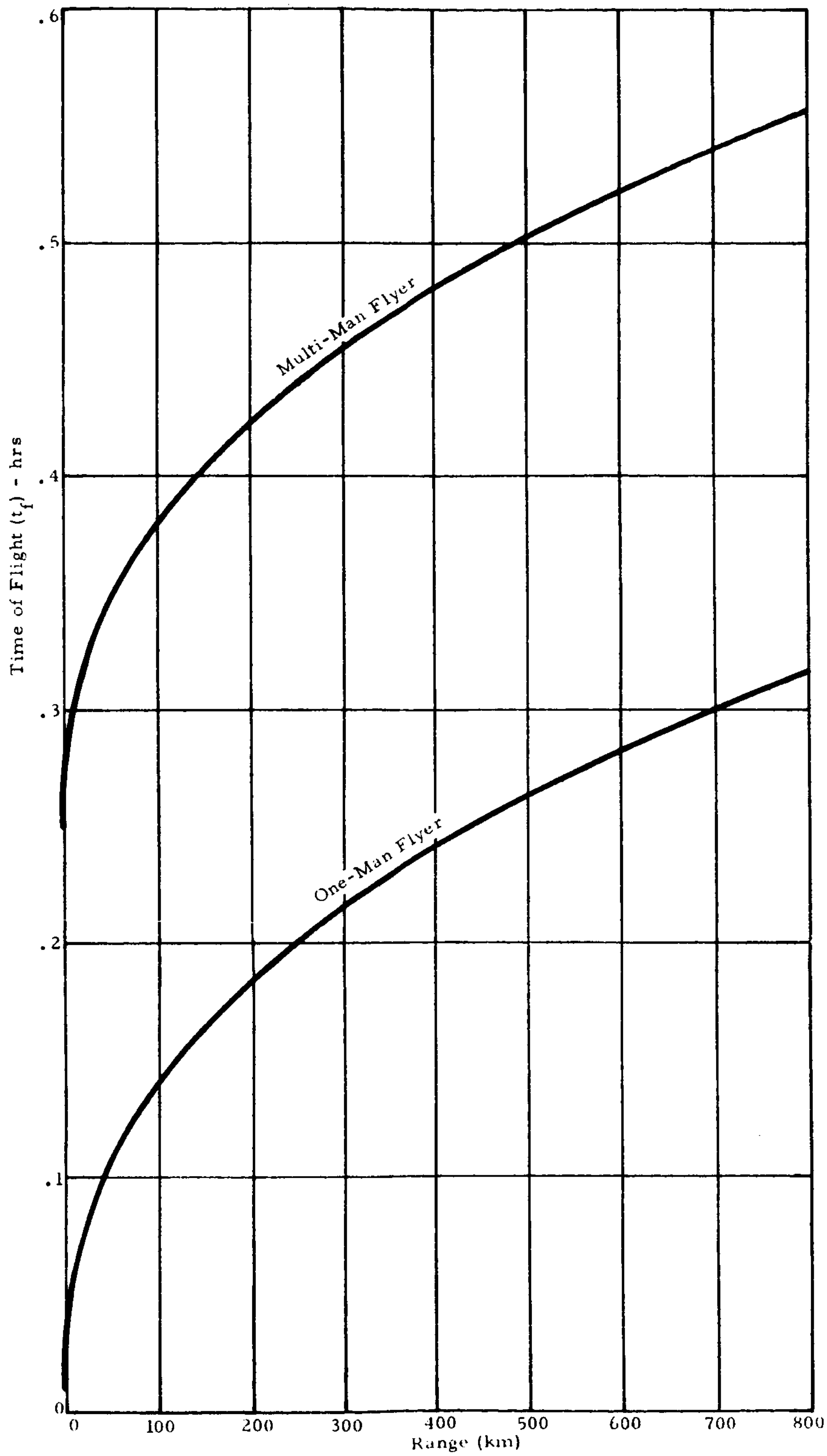


Figure D-2 Time of Flight vs Range

D. 2 ROVER DATA

The Rover technical data used in the computer program are contained in Table D-2. The items will be discussed by number as needed.

1. Vehicle Number - This is the number used to identify the vehicle in the computer. Flyers are listed first, followed by Rovers and base support vehicles in that order.

6. Unfueled Mass - See Glossary

7. Total Assignable Mass W_o - See Glossary

9. Radius of Operation Limit - This is a limit beyond which some vehicles cannot operate. The 3.0-km limit is the maximum walk-back distance. The 8.0-km limit is a line-of-sight limit.

10. Storage Losses - Applicable to vehicles with cryogenics.

12. Those vehicles without cabin are limited to PLSS operations. Those with cabin are charged with items 13, 14, and 15.

14. The expendables loss per egress/ingress cycle includes not only the airlock losses but also an amount of mass for EVA. For vehicles with one-man airlock, it is assumed that 1 PLSS charge per EVA is required. For two-man airlocks, it is assumed that 1.5 PLSS charges per EVA are required.

16. The power system type is required for handling mobility expendables. Those with batteries are charged with a fixed battery mass per kilometer traveled during the longest sortie (item 17). Those with

TABLE D-2

ROVER TECHNICAL DATA

Item													
1. VEHICLE NUMBER	14	15	16	17	18	19	20	21	22	23	24	25	26
2. CODE NAME	R0AE	R0BE	R0CE	R1AE	R1A(I)E	R1BE	R1B(I)E	R1DE	R2C(I)E	R3AE	R3BE	R3CE	R3DE
3. CLASS E - EXPLORATION R - RESCUE B - BASE SUPPORT	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R	E, R
4. VEHICLE TYPE	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover	Rover
5. REMOTE CONTROL CAPABILITY	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6. UNFUELED MASS (KG)	56.9	51.9	83.9	88.9	108.9	264.1	659.2	883.2	2065.2	3197.6	3723.4	2320.6	3512.0
7. TOTAL ASSIGNABLE MASS W_o (KG)	5.2	117.7	64.5	199.1	270.1	599.9	612.8	1051.8	1332.8	2359.4	3922.6	1505.4	4932.0
8. MAXIMUM VEHICLE CREW SIZE	0	0	0	1	1	1	1	1	2	3	3	3	3
9. RADIUS OF OPERATION LIMIT	None	3.0	None	3.0	3.0	8.0	None	None	None	None	None	None	None
10. STORAGE LOSSES - W_E (KG)													
1 month	0	0	0	0	0	0	0	5	45	53	62	46	5
2 months	0	0	0	0	0	0	0	10	90	106	124	92	10
3 months	0	0	0	0	0	0	0	15	135	155	185	137	15
4 months	0	0	0	0	0	0	0	20	180	207	246	182	20
5 months	0	0	0	0	0	0	0	25	225	259	308	228	25
6 months	0	0	0	0	0	0	0	30	270	311	370	273	30
11. MAXIMUM SPEED (KM/HR)													
ELMS MARIA MANNED	0	4.14	0	5.2	5.2	8.3	8.3	8.3	10.3	10.3	10.3	10.3	10.3
ELMS MARIA UNMANNED	0.414	0	1.03	0	0	0	2.1	2.1	3.1	3.1	3.1	3.1	3.1
ELMS HIGHLANDS MANNED	0	3.86	0	4.8	4.8	7.7	7.7	7.7	9.7	9.7	9.7	9.7	9.7
ELMS HIGHLANDS UNMANNED	0.386	0	0.97	0	0	0	1.9	1.9	2.9	2.9	2.9	2.9	2.9
ELMS 50/50 MANNED	0	4.0	0	5.0	5.0	8.0	8.0	8.0	10.0	10.0	10.0	10.0	10.0
ELMS 50/50 UNMANNED	0.4	0	1.0	0	0	0	2.0	2.0	3.0	3.0	3.0	3.0	3.0
12. CABIN	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
13. LIFE SUPPORT EXPENDABLES RATE (KG/MAN-DAY)	-	-	-	-	-	-	-	7.37	3.87	2.40	2.40	3.87	5.90
14. EXPENDABLES LOSS PER EGRESS/INGRESS CYCLE (KG)	-	-	-	-	-	-	-	4.56	4.02	5.99	5.99	5.91	5.99
15. CABIN LEAK RATE (KG/DAY)	-	-	-	-	-	-	-	0.94	2.50	2.70	2.95	2.50	2.95
16. POWER SYSTEM TYPE B - BATTERY RB - RTG (OR RTIG)-BATTERY F - FUEL CELL	RB	B	RB	B	B	B	RB	RB	F	F	F	F	RB
17. MOBILITY EXPENDABLES													
$W_1 = K_1 + K_2 R + K_3 R^2$													
ELMS MARIA													
K_1 (KG)	-	0	-	0	0	0	-	-	0	0	0	0	-
K_2 (KG/KM)	-	0.89	-	1.35	1.82	2.02	-		0.218	0.316	0.475	0.247	-
K_3 (KG/KM^2)	-	0	-	0	0	0		-	0	0	0	0	
ELMS HIGHLANDS													
K_1 (KG)	-	0	-	0	0	0	-	-	0	0	0	0	-
K_2 (KG/KM)	-	0.91	-	1.37	1.86	2.06	-	-	0.222	0.354	0.485	0.253	-
K_3 (KG/KM^2)	-	0	-	0	0	0	-		0	0	0	0	-
ELMS 50/50													
K_1 (KG)	-	0	-	0	0	0	-	-	0	0	0	0	-
K_2 (KG/KM)	-	0.90	-	1.36	1.84	2.04	-	-	0.220	0.350	0.480	0.250	-
K_3 (KG/KM^2)	-	0	-	0	0	0	-	-	0	0	0	0	-
$W_1 = K_A$ (R/D) (KG)													
K_A (KG/KM/DAY) - ELMS MARIA	0.574	-	2.82	-	-	-	2.44	3.55	-	-	-	-	19.80
ELMS HIGHLANDS	0.586	-	2.88	-	-	-	2.48	3.63	-	-	-	-	20.20
ELMS 50/50	0.580	-	2.85	-	-	-	2.46	3.59		-	-	-	20.03
$(R/D)_{MAX}$ (KM/DAY)	3.2	-	4.1	-	-	-	48.0	62.5	-	-	-	-	38.0

fuel cell systems are charged a fixed rate per kilometer of total distance traveled. Those with RTG or RTIG battery systems are charged a fixed rate under item 17 with an additional constraint on the maximum number of kilometers of travel per day.

D. 3 BASE SUPPORT VEHICLE DATA

Table D-3 contains the stored data on base support vehicle. Again, each item will be discussed by number as needed.

1. Vehicle Number - This is the index number assigned to the vehicle within the computer. Flyers are listed first, followed by Rovers, then base support.

6. Appendages Available - Appendages required are called for in the questionnaire by name. The mass of the compatible appendage is then deducted from payload capability except for vehicle 32. For this vehicle, the appendages are fixed, and are already included in the vehicle mass. For this reason, their mass is entered at 0 kg. For all prime movers, a trailer hitch and power winch have been assumed fixed and therefore subtracted from the nominal payload capability.

8. Cargo Capacity - For a prime mover-trailer combination, the payload capability is the sum of the individual capabilities.

10. Range/Sortie - This figure is a nominal figure based on going out with full cargo and returning empty.

11. Sortie Duration - This is a nominal figure based on a given drive time duty cycle.

12. Vehicle Mass - Exclusive of payload and crew but includes two spare PLSSs for vehicle 30 and 2 spare PLSSs plus 9.2 kg of food and water for vehicle 31.

TABLE D-3

BASE SUPPORT VEHICLE TECHNICAL DATA

Item		MASS (KG)							
1.	VEHICLE NUMBER:		27	28	29	30	31	32	33
2.	CODE NAME:		R0AB	R0BB	R0CB	R1AB	R1BB	R1CB	R2BB
3.	CLASS: E = EXPLORATION R = RESCUE B = BASE SUPPORT		B	B	B	B	B	B	B
4.	VEHICLE TYPE:		Trailer	Trailer	Trailer	Prime Mover	Prime Mover	Prime Mover	Prime Mover
5.	DRAWBAR PULL (lb):		-	-	-	222	367	750	560
6.	APPENDAGES AVAILABLE: A = BACKHOE + OUTRIGGERS B = BULLDOZER BLADE C = BACKHOE + OUTRIGGERS D = BACKHOE + OUTRIGGERS	 182 0 0 363	-	-	-	A	A	B C	D
7.	APPENDAGES DEDUCTIBLE FROM PAYLOAD?		-	-	-	Yes	Yes	No	Yes
8.	CARGO CAPACITY (KG):		987	2798	6441	300	300	1809	363
9.	COMPATIBLE TRAILERS:		-	-	-	27	27	27 28 29	27 28
10.	RANGE/SORTIE (KM): PRIME MOVER ALONE PRIME MOVER W/TRAILER		 - -	 - -	 - -	 32.0 12	 91.0 21.0	 15.0 (27) 15.0 (28) 15.0 (29) 12	 1110.0 (27) 220.0 (28) 171.0
11.	SORTIE DURATION (HRS): PRIME MOVER ALONE PRIME MOVER W/TRAILER		 - -	 - -	 - -	 6.0 6.0	 48.0 48.0	 6.0 (27) 6.0 (28) 6.0 (29) 6.0	 336.0 (27) 336.0 (28) 336.0
12.	VEHICLE MASS (KG):		285.0	600	1205.0	830	1493	2588	2897

APPENDIX E

COST DATA

This appendix documents all data used in the program pertaining to development costs of the 33 DPVs. These will be discussed briefly in order of presentation. A more detailed discussion will generally be found in Volume II, Book 5.

E. 1 TOTAL COSTS AND SCHEDULES

Each DPV has an associated nominal development schedule. This schedule is shown in months and in half years in Table E-1. The half-year figures are used in the program. Also associated with each vehicle is a cost C_o shown in thousands of dollars. This is the total cost of developing a single vehicle of the type shown. These figures are used in the logic shown in the overall diagram of Figure C-1 as schedule/total cost of set.

E. 2 LEARNING CURVES

Increased production is accompanied by decreased unit production costs. This decreased unit cost is maybe represented by the expression $C\alpha N^{-k}$, where C is the unit cost, N is the item number, and k is a constant representing the learning curve fraction. Table E-2 has been prepared using this expression to represent the learning achieved. The choice of the column used is dependent upon the number of production items which have previously been built during the development program.

An 85% learning curve (assuming all lunar vehicles follow an 85% learning curve) means that each time the quantity of produced units is doubled, the unit cost is decreased by 15% (100-85):

Unit Number	1	2	4	8	16
Decimal Fraction of Initial Unit Cost	1000	0.850	0.723	0.614	0.523

TABLE E-1

TOTAL COST AND SCHEDULES

Vehicle Number	Code Name	t_o (months)	t_o (1/2 years)	C_o (thousands)	Vehicle Number	Code Name	t_o (months)	t_o (1/2 years)	C_o (thousands)
1	F1A	30	5.00	11796	14	R0AE	32	5.33	43330
2	F1B	30	5.00	12787	15	R0BE	30	5.00	16300
3	F1C	30	5.00	19128	16	R0CE	34	5.67	54170
4	F2A	42	7.00	25539	17	R1AE	33	5.50	26450
5	F2B	42	7.00	28528	18	R1A(1)E	33	5.50	31300
6	F2C	42	7.00	32119	19	R1BE	33	5.50	43250
7	F2D	42	7.00	32920	20	R1B(1)E	36	6.00	93640
8	F2E	42	7.00	37086	21	R1DE	40	6.67	177370
9	F3A	42	7.00	29274	22	R2C(1)E	54	9.00	327610
10	F3B	42	7.00	35799	23	R3AE	56	9.33	345170
11	F3C	42	7.00	39355	24	R3BE	58	9.67	349280
12	F3D	42	7.00	47329	25	R3CE	56	9.33	332360
13	F3E	42	7.00	38037	26	R3DE	58	9.67	343470
					27	R0AB	28	4.50	16050
					28	R0BB	28	4.67	24180
					29	R0CB	30	5.00	25700
					30	R1AB	33	5.50	101210
					31	R1BB	40	6.67	184980
					32	R1CB	38	6.33	72750
					33	R2BB	54	9.00	335320

TABLE E-2

85% LEARNING RATES

Number of Previous Full Development Articles

Number of Production Articles	0		1		2		3		4		5		6		7		8		9
1	1.000																		
2	0.850	1	1.000																
3	0.773	2	0.909	1	1.000														
4	0.723	3	0.850	2	0.935	1	1.000												
5	0.687	4	0.807	3	0.887	2	0.949	1	1.000										
6	0.657	5	0.773	4	0.850	3	0.907	2	0.956	1	1.000								
7	0.634	6	0.746	5	0.820	4	0.877	3	0.924	2	0.966	1	1.000						
8	0.614	7	0.723	6	0.796	5	0.850	4	0.897	3	0.938	2	0.970	1	1.000				
9	0.598	8	0.704	7	0.773	6	0.827	5	0.872	4	0.912	3	0.943	2	0.972	1	1.000		
10	0.584	9	0.687	8	0.755	7	0.808	6	0.850	5	0.890	4	0.921	3	0.950	2	0.977	1	1.000
11	0.571	10	0.672	9	0.739	8	0.790	7	0.832	6	0.872	5	0.901	4	0.928	3	0.955	2	0.978
12	0.559	11	0.657	10	0.723	9	0.773	8	0.815	7	0.850	6	0.882	5	0.909	4	0.935	3	0.957
13	0.549	12	0.646	11	0.710	10	0.759	9	0.800	8	0.837	7	0.866	6	0.893	5	0.918	4	0.940
14	0.540	13	0.635	12	0.699	11	0.747	10	0.787	9	0.823	8	0.850	7	0.878	6	0.903	5	0.924
15	0.531	14	0.625	13	0.687	12	0.734	11	0.773	10	0.809	9	0.838	8	0.863	7	0.888	6	0.909
16	0.523	15	0.614	14	0.677	13	0.723	12	0.762	11	0.797	10	0.825	9	0.850	8	0.875	7	0.896
17	0.515	16	0.606	15	0.666	14	0.712	13	0.751	12	0.785	11	0.812	10	0.837	9	0.861	8	0.882
18	0.508	17	0.598	16	0.657	15	0.703	14	0.741	13	0.773	12	0.801	11	0.826	10	0.850	9	0.870
19	0.502	18	0.591	17	0.649	16	0.694	15	0.732	14	0.765	13	0.792	12	0.816	11	0.839	10	0.860
20	0.496	19	0.584	18	0.642	17	0.687	16	0.723	15	0.756	14	0.782	13	0.807	12	0.831	11	0.850
21	0.490	20	0.576	19	0.634	18	0.677	17	0.714	16	0.747	15	0.773	14	0.797	13	0.819	12	0.839
22	0.485	21	0.571	20	0.627	19	0.671	18	0.707	17	0.739	16	0.765	15	0.789	14	0.811	13	0.830
23	0.480	22	0.565	21	0.621	20	0.664	19	0.700	18	0.732	17	0.757	16	0.780	15	0.803	14	0.822
24	0.475	23	0.559	22	0.614	21	0.657	20	0.692	19	0.723	18	0.749	17	0.773	16	0.794	15	0.813
25	0.471	24	0.554	23	0.609	22	0.651	21	0.687	20	0.718	19	0.743	18	0.766	17	0.788	16	0.806
26	0.467	25	0.549	24	0.604	23	0.646	22	0.681	21	0.712	20	0.737	19	0.759	18	0.781	17	0.800
27	0.463	26	0.544	25	0.598	24	0.640	23	0.675	22	0.706	21	0.730	20	0.753	19	0.773	18	0.793
28	0.459	27	0.540	26	0.593	25	0.635	24	0.669	23	0.700	22	0.723	21	0.746	20	0.768	19	0.786
29	0.455	28	0.535	27	0.589	26	0.629	25	0.663	24	0.663	23	0.718	22	0.740	21	0.761	20	0.779
30	0.451	29	0.531	28	0.584	27	0.624	26	0.657	25	0.687	24	0.711	23	0.733	22	0.754	21	0.773

The factors which contribute to the decrease in production costs are operation learning, improved methods, management learning, debugging, and increased production rates.

Table E-3 contains the learning curve data for each DPV. The learning curve column of Table E-2 which is applicable to each vehicle is first indicated, followed by the cost of the first flight article in column 1. The figures in column 2 to 20 are then computed by applying the appropriate multiplication factors from Table E-2 to the cost of the first article in column 1.

The learning curve data of Table E-3 are used in the logic block of Figure C-1, labeled Schedule/Total Cost of Set.

E.3 PRIOR DEVELOPMENT COST SAVINGS MATRICES

In determining the cost of a singular vehicle within an evolution, the total cost C_o of Table E-1 is reduced on the basis of the development of prior vehicles in the evolution. This is done for 18 cost categories as shown in Table E-4. For each cost category a cost reduction matrix, called here a ΔC matrix, has been developed. These matrices are shown in Tables E-5 through E-22. In each category the cost reduction applicable to the vehicle being costed is first found for each prior vehicle in the evolution. The maximum of these values is then used as the net cost savings in that category. More details on the ΔC matrices will be found in Book 5.

TABLE E-3

LEARNING CURVES FOR DPV'S

Vehicle Number	Code Name	Learning Curve Column	NUMBER OF VEHICLES PRODUCED 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	F1A	2	1024	957	908	870	840	815	792	773	757	740	727	716	703	693	682	673	665	657	649	642
2	F1B	2	1074	1004	953	913	881	855	830	811	794	777	763	751	738	727	715	706	697	690	681	673
3	F1C	2	1707	1596	1514	1451	1400	1359	1320	1289	1261	1234	1212	1193	1173	1156	1137	1121	1108	1096	1082	1070
4	F2A	2	1973	1845	1750	1677	1618	1571	1525	1490	1458	1426	1401	1379	1355	1336	1314	1296	1280	1267	1251	1237
5	F2B	2	2096	1960	1859	1782	1719	1668	1620	1582	1549	1515	1488	1465	1440	1419	1396	1377	1360	1346	1329	1314
6	F2C	2	2348	2195	2083	1996	1925	1869	1815	1773	1735	1698	1667	1641	1613	1590	1564	1543	1524	1507	1489	1472
7	F2D	2	2480	2319	2200	2108	2034	1974	1917	1872	1833	1793	1761	1734	1704	1679	1652	1629	1610	1592	1572	1554
8	F2E	2	2347	2194	2082	1995	1925	1868	1814	1772	1734	1697	1666	1641	1612	1589	1563	1542	1523	1507	1488	1472
9	F3A	2	2281	2133	2023	1939	1870	1816	1763	1722	1686	1649	1620	1594	1567	1544	1519	1499	1480	1464	1446	1430
10	F3B	2	2760	2581	2448	2346	2263	2197	2133	2084	2040	1995	1960	1929	1896	1869	1838	1813	1791	1772	1750	1731
11	F3C	2	3375	3155	2994	2869	2767	2687	2609	2548	2494	2440	2396	2359	2319	2285	2248	2217	2190	2167	2140	2116
12	F3D	2	4770	4460	4231	4055	3911	3797	3687	3601	3525	3449	3386	3334	3277	3229	3177	3134	3096	3062	3024	2991
13	F3E	2	2487	2325	2206	2114	2039	1980	1922	1878	1838	1798	1766	1738	1709	1684	1656	1634	1614	1597	1577	1559
14	R0AE	2	2000	1870	1774	1700	1640	1592	1546	1510	1478	1446	1420	1398	1374	1354	1332	1314	1298	1284	1268	1254
15	R0BE	2	1500	1403	1331	1275	1230	1194	1160	1133	1109	1085	1065	1049	1031	1016	999	986	974	963	951	941
16	R0CE	2	3000	2805	2661	2550	2460	2388	2319	2265	2217	2169	2130	2097	2061	2031	1998	1971	1947	1926	1902	1881
17	R1AE	2	2300	2151	2040	1955	1886	1831	1778	1737	1700	1663	1633	1608	1580	1557	1532	1511	1493	1477	1458	1442
18	R1A(1)E	2	2900	2712	2572	2465	2378	2308	2242	2190	2143	2097	2059	2027	1992	1963	1931	1905	1882	1862	1839	1818
19	R1BE	2	3840	3590	3406	3264	3148	3056	2968	2899	2837	2776	2726	2684	2638	2599	2557	2523	2492	2465	2435	2408
20	R1B(1)E	2	6760	6321	5996	5746	5543	5381	5225	5104	4996	4887	4800	4725	4644	4576	4502	4441	4387	4340	4286	4239
21	R1DE	5	9250	8935	8676	8436	8232	8066	7862	7742	7612	7483	7372	7261	7150	7076	6993	6910	6836	6771	6688	6642
22	R2C(1)E	5	13200	12751	12381	12038	11748	11510	11220	11048	10863	10678	10520	10362	10203	10098	9979	9860	9755	9662	9544	9478
23	R3AE	5	14000	13524	13132	12768	12460	12208	11900	11718	11522	11326	11158	10990	10822	10710	10584	10458	10346	10248	10122	10052
24	R3BE	5	14200	13717	13319	12950	12638	12382	12070	11885	11686	11487	11317	11147	10976	10863	10735	10607	10494	10394	10267	10196
25	R3CE	5	13500	13041	12663	12312	12015	11772	11475	11299	11110	10921	10759	10597	10435	10327	10206	10085	9977	9882	9761	9693
26	R3DE	5	15000	14490	14070	13680	13350	13080	12750	12555	12345	12135	11955	11775	11595	11475	11340	11205	11085	10980	10845	10770
27	R0AB	2	1050	982	931	893	861	836	812	792	776	759	746	734	721	711	699	690	681	674	666	658
28	R0BB	2	1160	1085	1029	986	951	923	897	876	857	839	824	811	797	785	773	762	753	745	735	727
29	R0CB	2	1260	1178	1118	1071	1033	1003	974	951	931	911	895	881	866	853	839	828	818	809	799	790
30	R1AB	2	7050	6592	6253	5993	5781	5612	5450	5323	5210	5097	5006	4928	4843	4772	4695	4632	4575	4526	4470	4420
31	R1BB	5	9600	9274	9005	8755	8544	8371	8160	8035	7901	7766	7651	7536	7421	7344	7258	7171	7094	7027	6941	6893
32	R1CB	4	5800	5545	5359	5203	5058	4930	4826	4727	4640	4565	4483	4420	4356	4298	4246	4193	4141	4101	4060	4014
33	R2BB	5	13400	12944	12569	12221	11926	11685	11390	11216	11028	10841	10680	10519	10358	10251	10130	10010	9903	9809	9688	9621

TABLE E-4

ΔC MATRIX LIST

Cost Category	Table
1. Mobility Development	E-5
2. Cabin/Crew Station Development	E-6
3. Power Development	E-7
4. Communications Development	E-8
5. Navigation and Guidance Development	E-9
6. Remote Control Development	E-10
7. Appendages Development	E-11
8. Landing Gear and Structure Development	E-12
9. Propulsion System Development	E-13
10. Communications, Guidance, and Navigation Development	E-14
11. Subsystem Integration Development and Subsystem Test Article	E-15
12. System Integration Development and System Test Article	E-16
13. Lunar GSE Development	E-17
14. Remote Control GSE Development and Support	E-18
15. Earth GSE Development	E-19
16. Delivered GSE	E-20
17. Training Aids and Support Equipment	E-21
18. Use of Government Facilities	E-22

TABLE E-5

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Mobility Development

PRIOR VEHICLE DEVELOPED

CONCEPT TO BE DEVELOPED	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	3,500		2,000	2,000	2,000	2,000	2,000	2,000	2,000	500	500	500	500	500	1,000	1,000	1,000	2,000	2,000	2,000	500
ROBE	6,500	1,500		3,500	2,000	2,000	2,000	2,000	2,000	500	500	500	500	500	1,000	1,000	1,000	2,000	2,000	2,000	500
ROCE	9,500	2,500	3,000		7,000	7,000	5,000	5,000	5,000	2,000	2,000	2,000	2,000	2,000	1,000	1,000	1,000	5,000	5,000	5,000	2,000
R1AE	9,000	1,500	2,500	5,000		8,000	7,000	7,000	7,000	2,000	2,000	2,000	2,000	2,000	1,000	1,000	1,000	7,000	7,000	7,000	2,000
R1A(1)E	11,000	1,500	2,500	5,000	8,000		9,000	9,000	9,000	2,000	2,000	2,000	2,000	2,000	1,000	1,000	1,000	9,000	9,000	9,000	2,000
R1BE	11,280	1,500	1,500	3,000	7,000	9,000		11,000	11,000	5,000	5,000	5,000	5,000	5,000	5,000	3,000	3,000	11,000	11,000	11,000	5,000
R1B(1)E	11,280	1,500	1,500	3,000	7,000	9,000	11,000		11,000	5,000	5,000	5,000	5,000	5,000	5,000	3,000	3,000	11,000	11,000	11,000	5,000
R1DE	11,500	1,500	1,500	3,000	7,000	9,000	11,000	11,000		5,000	5,000	5,000	5,000	5,000	5,000	3,000	3,000	11,200	11,200	11,000	5,000
R2C(1)E	28,700	1,000	1,000	1,000	4,000	6,000	7,000	7,000	7,000		20,000	20,000	28,500	20,000	4,000	6,000	5,000	7,000	7,000	7,000	28,400
R3AE	29,300	1,000	1,000	1,000	4,000	6,000	7,000	7,000	7,000	22,000		29,000	22,000	29,000	4,000	5,000	7,000	7,000	7,000	7,000	22,000
R3BE	29,300	1,000	1,000	1,000	4,000	6,000	7,000	7,000	7,000	22,000	29,000		22,000	29,000	4,000	5,000	7,000	7,000	7,000	7,000	22,000
R3CE	28,700	1,000	1,000	1,000	4,000	6,000	7,000	7,000	7,000	28,400	20,000	20,000		20,000	4,000	6,000	5,000	7,000	7,000	7,000	28,400
R3DE	29,300	1,000	1,000	1,000	4,000	6,000	7,000	7,000	7,000	22,000	29,000	29,000	22,000		4,000	5,000	7,000	7,000	7,000	7,000	22,000
ROAB	9,000	1,000	1,000	1,000	6,000	6,000	7,500	7,500	7,500	4,500	4,000	4,000	4,500	4,000		4,500	4,000	7,500	7,500	7,000	4,500
ROBB	15,140	1,000	1,000	1,000	4,000	4,000	3,000	3,000	3,000	13,000	7,000	7,000	13,000	7,000	5,000		10,000	3,000	3,000	1,500	13,000
ROCB	15,740	1,000	1,000	1,000	4,000	4,000	2,500	2,500	2,500	7,000	13,600	13,600	7,000	13,600	5,000	10,000		2,500	2,500	1,500	7,000
R1AB	11,300	1,500	1,500	3,000	7,000	9,000	11,200	11,200	11,200	5,000	5,000	5,000	5,000	5,000	5,000	3,000	3,000		11,200	11,000	5,000
R1BB	11,600	1,500	1,500	3,000	7,000	9,000	11,500	11,500	11,500	5,000	5,000	5,000	5,000	5,000	5,000	3,000	3,000	11,500		11,300	5,000
R1CB	12,200	500	500	500	3,000	3,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	5,000	3,000	3,000	7,000	7,000		7,000
R2BB	28,800	1,000	1,000	1,000	4,000	4,000	7,000	7,000	7,000	28,700	20,000	20,000	28,700	20,000	4,000	6,000	5,000	7,000	7,000	7,000	

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TABLE E-6

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Crew Station/Cabin Development

PRIOR VEHICLE DEVELOPED

CONCEPT TO BE DEVELOPED	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	1,500	-	-	-		1,400	200	200	-	-	-	-	-	-	-	-	-	200	-	500	-
R1A(1)E	1,800	-	-	-	1,400		200	200	-	-	-	-	-	-	-	-	-	200	-	500	-
R1BE	4,050	-	-	-	-	-		3,800	-	-	-	-	-	-	-	-	-	3,800	-	3,800	-
R1B(1)E	4,050	-	-	-	-	-	3,800		-	-	-	-	-	-	-	-	-	3,800	-	3,800	-
R1DE	22,000	-	-	-	-	-	-	-		8,000	8,000	8,000	8,000	8,000	-	-	-	-	21,800	-	8,000
R2C(1)E	35,310	-	-	-	-	-	-	-	8,000		17,000	17,000	33,700	17,000	-	-	-	-	8,000	-	35,000
R3AE	40,750	-	-	-	-	-	-	-	8,000	20,000		37,500	17,000	37,500	-	-	-	-	8,000	-	20,000
R3BE	41,750	-	-	-	-	-	-	-	8,000	20,000	38,750		17,000	41,500	-	-	-	-	8,000	-	20,000
R3CE	37,000	-	-	-	-	-	-	-	8,000	33,000	17,000	17,000		17,000	-	-	-	-	8,000	-	33,000
R3DE	44,750	-	-	-	-	-	-	-	8,000	20,000	40,750	41,750	17,000		-	-	-	-	8,000	-	20,000
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	4,300	-	-	-	-	-	3,800	3,800	-	-	-	-	-	-	-	-	-		-	4,000	-
R1BB	22,300	-	-	-	-	-	-	-	19,300	10,000	10,000	10,000	10,000	10,000	-	-	-	-		-	10,000
R1CB	5,000	-	-	-	800	800	3,000	3,000	-	-	-	-	-	-	-	-	-	3,800	-		-
R2BB	36,000	-	-	-	-	-	-	-	8,000	32,000	15,000	15,000	32,000	15,000	-	-	-	-	8,000	-	

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TABLE E-7

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Power Development

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	1,670		400	700	400	400	400	700	100	-	-	-	-	-	-	-	-	400	-	400	-
ROBE	1,000	400		400	400	400	400	400	-	-	-	-	-	-	-	-	-	400	-	400	-
ROCE	1,670	700	400		400	400	400	700	100	-	-	-	-	-	-	-	-	400	-	400	-
R1AE	1,150	400	400	400		400	400	400	-	-	-	-	-	-	-	-	-	400	-	400	-
R1A(1)E	1,250	400	400	400	400		400	400	-	-	-	-	-	-	-	-	-	400	-	400	-
R1BE	1,250	400	400	400	400	400		400	-	-	-	-	-	-	-	-	-	1,100	-	400	-
R1B(1)E	1,670	700	400	700	400	400	400		400	-	-	-	-	-	-	-	-	1,300	-	400	-
R1DE	4,000	100	-	100	-	-	-	400		-	-	-	-	-	-	-	-	-	3,600	-	-
R2C(1)E	24,020	-	-	-	-	-	-	-	-		20,000	20,000	23,700	-	-	-	-	-	-	-	23,500
R3AE	24,100	-	-	-	-	-	-	-	-	21,000		21,000	21,000	-	-	-	-	-	-	-	21,000
R3BE	24,110	-	-	-	-	-	-	-	-	21,000	21,000		21,000	-	-	-	-	-	-	-	21,000
R3CE	24,020	-	-	-	-	-	-	-	-	23,700	20,000	20,000		-	-	-	-	-	-	-	23,500
R3DE	10,000	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
ROAB	50	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	1,700	400	400	400	400	400	1,000	1,300	-	-	-	-	-	-	-	-	-		-	400	-
R1BB	4,100	-	-	-	-	-	-	-	3,700	-	-	-	-	-	-	-	-	-		-	-
R1CB	1,800	400	400	400	400	400	400	400	-	-	-	-	-	-	-	-	-	400	-		-
R2BB	24,120	-	-	-	-	-	-	-	-	23,720	20,000	20,000	23,500	-	-	-	-	-	-	-	

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TABLE E-8

PRIOR DEVELOPMENT SAVINGS MATRIX

(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Communications Development

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED: NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	2,700		-	1,500	-	-	-	1,500	1,500	1,500	1,500	1,500	1,500	1,500	-	-	-	1,500	1,500	-	1,500
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	2,700	1,500	-		-	-	-	1,500	1,500	1,500	1,500	1,500	1,500	1,500	-	-	-	1,500	1,500	-	1,500
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	9,630	1,500	-	1,500	-	-	-		9,400	9,000	9,000	9,000	9,000	9,000	-	-	-	9,500	9,400	-	9,000
R1DE	9,630	1,500	-	1,500	-	-	-	9,400		9,000	9,000	9,000	9,000	9,000	-	-	-	9,400	9,400	-	9,000
R2C(1)E	11,500	1,500	-	1,500	-	-	-	8,000	8,000		9,000	9,000	9,000	9,000	-	-	-	8,000	8,000	-	11,300
R3AE	12,000	1,500	-	1,500	-	-	-	8,000	8,000	8,000		11,800	9,000	11,800	-	-	-	8,000	8,000	-	8,000
R3BE	12,000	1,500	-	1,500	-	-	-	8,000	8,000	8,000	11,800		9,000	11,800	-	-	-	8,000	8,000	-	8,000
R3CE	11,500	1,500	-	1,500	-	-	-	8,000	8,000	11,300	9,000	9,000		9,000	-	-	-	8,000	8,000	-	11,300
R3DE	12,000	1,500	-	1,500	-	-	-	8,000	8,000	8,000	11,800	11,800	9,000		-	-	-	8,000	8,000	-	8,000
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	9,630	1,500	-	1,500	-	-	-	9,500	9,400	9,000	9,000	9,000	9,000	9,000	-	-	-		9,400	-	9,000
R1BB	9,630	1,500	-	1,500	-	-	-	9,500	9,500	9,000	9,000	9,000	9,000	9,000	-	-	-	9,500		-	9,000
R1CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	11,500	1,500	-	1,500	-	-	-	8,000	8,000	11,450	10,000	10,000	11,300	10,000	-	-	-	8,000	8,000	-	

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TABLE E-9

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Navigation & Guidance Development

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	300		-	250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	300	250	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	1,140	-	-	-	-	-	-		1,040	-	-	-	-	-	-	-	-	1,040	1,040	-	-
R1DE	1,140	-	-	-	-	-	-	1,040		-	-	-	-	-	-	-	-	1,040	1,040	-	-
R2C(1)E	5,720	-	-	-	-	-	-	-	-		5,600	5,600	5,600	5,600	-	-	-	-	-	-	5,600
R3AE	5,720	-	-	-	-	-	-	-	-	5,600		5,600	5,600	5,600	-	-	-	-	-	-	5,600
R3BE	5,720	-	-	-	-	-	-	-	-	5,600	5,600		5,600	5,600	-	-	-	-	-	-	5,600
R3CE	5,720	-	-	-	-	-	-	-	-	5,600	5,600	5,600		5,600	-	-	-	-	-	-	5,600
R3DE	5,720	-	-	-	-	-	-	-	-	5,600	5,600	5,600	5,600		-	-	-	-	-	-	5,600
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	1,140	-	-	-	-	-	-	1,040	1,040	-	-	-	-	-	-	-	-		1,040	-	-
R1BB	1,140	-	-	-	-	-	-	1,040	1,040	1,040	-	-	-	-	-	-	-	1,040		-	-
R1CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	5,720	-	-	-	-	-	-	-	-	5,600	5,600	5,600	5,600	5,600	-	-	-	-	-	-	

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TABLE E-10

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Remote Control Development

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	5,500		-	5,000	-	-	-	500	500	200	200	200	200	200	-	-	-	500	200	-	200
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	5,500	5,000	-		-	-	-	500	500	200	200	200	200	200	-	-	-	500	200	-	200
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	10,190	2,000	-	2,000	-	-	-		8,000	5,000	5,000	5,000	5,000	5,000	-	-	-	10,190	8,000	-	5,000
R1DE	10,190	2,000	-	2,000	-	-	-	7,000		9,000	9,000	9,000	9,000	9,000	-	-	-	7,000	10,000	-	9,000
R2C(1)E	10,280	2,000	-	2,000	-	-	-	7,000	8,000		10,000	10,000	10,000	10,000	-	-	-	7,000	9,000	-	10,000
R3AE	10,300	2,000	-	2,000	-	-	-	7,000	8,000	9,000		10,000	10,000	10,000	-	-	-	7,000	8,000	-	10,000
R3BE	10,300	2,000	-	2,000	-	-	-	7,000	8,000	9,000	10,000		10,000	10,000	-	-	-	7,000	8,000	-	10,000
R3CE	10,280	2,000	-	2,000	-	-	-	7,000	8,000	10,000	10,000	10,000		10,000	-	-	-	7,000	8,000	-	10,000
R3DE	10,300	2,000	-	2,000	-	-	-	7,000	8,000	9,000	10,000	10,000	10,000		-	-	-	7,000	8,000	-	10,000
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	10,190	2,000	-	2,000	-	-	-	10,190	8,000	5,000	5,000	5,000	5,000	5,000	-	-	-		8,000	-	5,000
R1BB	10,190	2,000	-	2,000	-	-	-	7,000	10,190	9,000	8,000	8,000	8,000	8,000	-	-	-	-		-	9,000
R1CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	10,280	2,000	-	2,000	-	-	-	7,000	8,000	10,280	10,000	10,000	10,000	10,000	-	-	-	-	8,000	-	

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TABLE E-11

PRIOR DEVELOPMENT SAVINGS MATRIX

(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Appendages Development

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-
R1DE	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
R2C(1)E	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
R3AE	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
R3BE	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-
R3CE	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-
R3DE	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	4,200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		4,000	4,000	4,000
R1BB	4,200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,700		3,700	3,700
R1CB	6,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,000	4,000		4,000
R2BB	4,200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,700	3,700	3,700	

960-8

TABLE E-12

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

LANDING GEAR AND STRUCTURE DEVELOPMENT

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	180		160	100	-	-	-	-	-	-	-	-	-	-
F-1-B	220	150		100	-	-	-	-	-	-	-	-	-	-
F-1-C	410	-	-		-	-	-	-	-	-	-	-	-	-
F-2-A	1600	-	-	-		227	227	227	136	91	91	182	182	45
F-2-B	1746	-	-	-	248		248	248	149	99	99	198	198	50
F-2-C	1890	-	-	-	269	269		269	161	107	107	215	215	54
F-2-D	2090	-	-	-	297	297	297		178	119	119	237	237	59
F-2-E	1479	-	-	-	296	296	296	296		148	148	148	148	296
F-3-A	1988	-	-	-	56	56	56	56	113		282	225	225	113
F-3-B	2388	-	-	-	68	68	68	68	136	339		271	271	136
F-3-C	2950	-	-	-	84	84	84	84	-	335	335		419	168
F-3-D	3817	-	-	-	108	108	108	108	-	434	434	542		217
F-3-E	1698	-	-	-	85	85	85	85	255	255	255	340	340	

TABLE E-13

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

PROPULSION SYSTEM DEVELOPMENT

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	5300		4500	1935	4500	4500	4500	1935	743	1935	1260	900	743	743
F-1-B	5700	4500		1935	4500	4500	4500	1935	743	1935	1260	900	743	743
F-1-C	5500	1935	1935		1935	1935	1935	4500	855	4500	2925	1755	855	855
F-2-A	7112	4500	4500	1935		4500	4500	1935	743	1935	1260	900	743	743
F-2-B	7492	4500	4500	1935	4500		4500	1935	743	1935	1260	900	743	743
F-2-C	7412	4500	4500	1935	4500	4500		1935	743	1935	1260	900	743	743
F-2-D	7572	1935	1935	4500	1935	1935	1935		855	4500	2925	1755	855	855
F-2-E	10,544	1031	1031	1188	1031	1031	1031	1188		1188	1656	2500	6250	6250
F-3-A	7412	1935	1935	4500	1935	1935	1935	4500	855		2925	1755	855	855
F-3-B	8535	1400	1400	3250	1400	1400	1400	3250	1325	3250		3250	1325	1325
F-3-C	9559	1100	1100	2145	1100	1100	1100	2145	2200	2145	3575		2200	2200
F-3-D	11,354	1031	1031	1188	1031	1031	1031	1188	6250	1188	1656	2500		6250
F-3-E	10,724	1031	1031	1188	1031	1031	1031	1188	6250	1188	1656	2500	6250	

TABLE E-14

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

COMMUNICATIONS, NAVIGATION AND GUIDANCE, FLIGHT CONTROLS, ELECTRICAL POWER DEVELOPMENT

(Thousands of Dollars)

Concept to be Developed	No Prior Development	Prior Vehicle Developed												
		F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	150		150	-	-	-	-	-	-	-	-	-	-	-
F-1-B	150	150		-	-	-	-	-	-	-	-	-	-	-
F-1-C	2360	-	-		228	2360	228	228	228	2360	228	228	228	228
F-2-A	1996	-	-	228		228	228	228	228	228	228	228	228	228
F-2-B	2880	-	-	2360	228		228	228	228	2880	228	228	228	228
F-2-C	4616	-	-	228	228	228		4616	3330	228	4616	4616	4616	3330
F-2-D	4616	-	-	228	228	228	4616		3330	228	4616	4616	4616	3330
F-2-E	4960	-	-	228	228	228	3330	3330		228	3330	3330	4616	4960
F-3-A	2880	-	-	2360	228	2880	228	228	228		228	228	228	228
F-3-B	4616	-	-	228	228	228	4616	4616	3330	228		4616	4616	3330
F-3-C	4616	-	-	228	228	228	4616	4616	3330	228	4616		4616	3330
F-3-D	5500	-	-	228	228	228	4616	4616	3330	228	4616	4616		3330
F-3-E	4960	-	-	228	228	228	3330	3330	4960	228	3330	3330	4616	

TABLE E-15

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

SUBSYSTEM INTEGRATION
(Thousands of Dollars)

Concept to be Developed	No Prior Development	Prior Vehicle Developed: F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	700		70	70	70	70	70	70	70	70	70	70	70	70
F-1-B	800	80		80	80	80	80	80	80	80	80	80	80	80
F-1-C	1100	110	110		110	110	110	110	110	110	110	110	110	110
F-2-A	2300	230	230	230		230	230	230	230	230	230	230	230	230
F-2-B	2603	260	260	260	260		260	260	260	260	260	260	260	260
F-2-C	2990	299	299	299	299	299		299	299	299	299	299	299	299
F-2-D	3067	307	307	307	307	307	307		307	307	307	307	307	307
F-2-E	3648	365	365	365	365	365	365	365		365	365	365	365	365
F-3-A	2638	264	264	264	264	264	264	264	264		264	264	264	264
F-3-B	3338	334	334	334	334	334	334	334	334	334		334	334	334
F-3-C	3678	368	368	368	368	368	368	368	368	368	368		368	368
F-3-D	4440	444	444	444	444	444	444	444	444	444	444	444		444
F-3-E	3734	373	373	373	373	373	373	373	373	373	373	373	373	

TABLE E-15 (CONT.0

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Subsystem Integ. Devel. Subsystem Test Articles

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	2,200		400	400	400	400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	1,500	450		150	450	450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	3,600	600	600		600	600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	2,000	600	800	-		-	300	300	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	2,200	600	800	-	-		300	300	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	2,760	-	-	-	300	300		2,760	1,500	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	4,800	-	-	-	300	300	2,760		1,500	-	-	-	-	-	-	-	-	1,700	1,500	-	-
R1DE	30,000	-	-	-	-	-	1,000	1,000		5,000	5,000	5,000	5,000	5,000	-	-	-	1,000	15,000	-	5,000
R2C(1)E	73,810	-	-	-	-	-	-	-	5,000		57,700	57,700	57,700	57,700	-	-	-	-	5,000	-	57,700
R3AE	77,000	-	-	-	-	-	-	-	5,000	58,000		58,000	58,000	58,000	-	-	-	-	5,000	-	58,000
R3BE	77,500	-	-	-	-	-	-	-	5,000	58,000	58,500		58,500	58,500	-	-	-	-	5,000	-	58,500
R3CE	75,000	-	-	-	-	-	-	-	5,000	58,000	58,000	58,000		58,000	-	-	-	-	5,000	-	58,000
R3DE	79,000	-	-	-	-	-	-	-	5,000	59,000	59,000	59,000	59,000		-	-	-	-	5,000	-	59,000
ROAB	1,150	-	-	-	-	-	150	150	-	-	-	-	-	-		400	400	150	-	-	-
ROBB	2,130	-	-	-	-	-	-	-	-	630	-	-	630	-	400		400	-	-	-	630
ROCB	2,500	-	-	-	-	-	-	-	-	-	1,000	1,000	-	1,000	400	400		-	-	-	-
R1AB	5,700	-	-	-	500	500	1,000	1,700	1,000	-	-	-	-	-	-	-	-		1,000	-	-
R1BB	31,000	-	-	-	-	-	1,000	1,000	15,000	1,000	1,000	1,000	1,000	1,000	-	-	-	1,000		-	1,000
R1CB	5,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	74,700	-	-	-	-	-	-	-	5,000	50,700	50,700	50,700	50,700	50,700	-	-	-	-	5,000	-	

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TABLE E-16

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

SYSTEM INTEGRATION AND SYSTEM TEST ARTICLES

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	2100		420	420	210	210	210	210	210	210	210	210	210	210
F-1-B	2450	490		490	245	245	245	245	245	245	245	245	245	245
F-1-C	3907	781	781		391	391	391	391	391	391	391	391	391	391
F-2-A	5137	514	514	514		1027	1027	1027	514	1027	1027	1027	1027	514
F-2-B	5813	581	581	581	1163		1163	1163	581	1163	1163	1163	1163	581
F-2-C	6677	668	668	668	1335	1335		1335	668	1335	1335	1335	1335	668
F-2-D	6850	685	685	685	1370	1370	1370		685	1370	1370	1370	1370	685
F-2-E	8147	-	-	-	815	815	815	815		815	815	815	815	815
F-3-A	5891	589	589	589	1178	1178	1178	1178	1178		1178	1178	1178	589
F-3-B	7455	745	745	745	1491	1491	1491	1491	1491	1491		1491	1491	745
F-3-C	8215	821	821	821	1643	1643	1643	1643	1643	1643	1643		1643	821
F-3-D	9916	992	992	992	1983	1983	1983	1983	1983	1983	1983	1983		992
F-3-E	8839	-	-	-	834	834	834	834	834	834	834	834	834	

TABLE E-16 (CONT.)

PRIOR DEVELOPMENT SAVINGS MATRIX

(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT System Integration Devel. & System Test Article

CONCEPT TO BE DEVELOPED	NO PRIOR DEVEL.	PRIOR VEHICLE DEVELOPED: ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	8,000	X	-	1,000	100	100	-	-	-	-	-	-	-	-	-	-	-	200	-	500	-
ROBE	3,500	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	9,000	1,000	-	X	100	100	-	-	-	-	-	-	-	-	-	-	-	500	-	500	-
R1AE	6,500	200	-	200	X	2,000	-	-	-	-	-	-	-	-	-	-	-	500	-	500	-
R1A(1)E	7,500	200	-	200	2,000	X	-	-	-	-	-	-	-	-	-	-	-	500	-	500	-
R1BE	10,000	200	-	500	500	500	X	2,000	2,000	-	-	-	-	-	-	-	-	2,000	2,000	500	-
R1B(1)E	17,710	500	-	500	500	500	3,800	X	3,800	-	-	-	-	-	-	-	-	12,700	3,800	500	-
R1DE	45,000	-	-	-	-	-	1,000	1,000	X	5,000	4,000	4,000	5,000	4,000	-	-	-	1,000	31,000	-	5,000
R2C(1)E	78,430	-	-	-	-	-	-	-	5,000	X	34,400	34,400	34,400	34,400	-	-	-	-	5,000	-	34,400
R3AE	84,500	-	-	-	-	-	-	-	5,000	36,000	X	37,000	37,000	37,000	-	-	-	-	5,000	-	36,000
R3BE	85,800	-	-	-	-	-	-	-	5,000	36,000	37,000	X	37,000	37,000	-	-	-	-	5,000	-	36,000
R3CE	80,000	-	-	-	-	-	-	-	5,000	38,000	35,000	35,000	X	35,000	-	-	-	-	5,000	-	38,000
R3DE	87,500	-	-	-	-	-	-	-	5,000	23,000	38,000	38,000	38,000	X	-	-	-	-	5,000	-	23,000
ROAB	2,500	-	-	-	-	-	1,200	1,200	800	-	-	-	-	-	X	200	200	800	800	-	-
ROBB	3,150	-	-	-	-	-	-	-	-	1,250	-	-	1,250	-	200	X	200	-	-	-	1,250
ROCB	3,600	-	-	-	-	-	-	-	-	-	1,600	1,600	-	1,600	200	200	X	-	-	-	-
R1AB	18,700	200	-	500	500	500	1,800	12,700	1,500	-	-	-	-	-	-	-	-	X	1,500	-	-
R1BB	45,800	-	-	-	-	-	500	500	31,000	5,000	5,000	5,000	5,000	5,000	-	-	-	-	X	-	5,000
R1CB	20,500	-	-	-	500	500	500	500	-	-	-	-	-	-	-	-	-	-	-	X	-
R2BB	79,150	-	-	-	-	-	-	-	5,000	56,150	34,400	34,400	56,150	34,400	-	-	-	-	5,000	-	X

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TABLE E-17

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

LUNAR GSE DEVELOPMENT

(Thousands of Dollars)

Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	713		713	713	576	576	576	576	576	576	576	576	576	576
F-1-B	713	713		713	576	576	576	576	576	576	576	576	576	576
F-1-C	1696	713	713		950	950	950	950	950	950	950	950	950	950
F-2-A	1980	126	126	733		1980	1980	1980	953	1980	1980	1980	1980	953
F-2-B	2230	126	126	733	1980		2230	2230	953	2230	2230	2230	2230	953
F-2-C	2230	126	126	733	1980	2230		2230	953	2230	2230	2230	2230	953
F-2-D	2230	126	126	733	1980	2230	2230		953	2230	2230	2230	2230	953
F-2-E	953	126	126	733	953	953	953	953		953	953	953	953	953
F-3-A	2420	126	126	733	1980	2230	2230	2230	953		2420	2420	2420	953
F-3-B	2420	126	126	733	1980	2230	2230	2230	953	2420		2420	2420	953
F-3-C	2420	126	126	733	1980	2230	2230	2230	953	2420	2420		2420	953
F-3-D	2420	126	126	733	1980	2230	2230	2230	953	2420	2420	2420		953
F-3-E	953	126	126	733	953	953	953	953	953	953	953	953	953	

TABLE E-17 (CONT.)

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Lunar GSE Development

CONCEPT TO BE DEVELOPED	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
	PRIOR VEHICLE DEVELOPED																				
ROAE	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	50	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	400	-	-	-		300	100	100	100	100	100	100	100	100	200	100	100	100	100	100	100
R1A(1)E	400	-	-	-	300		100	100	100	100	100	100	100	100	200	100	100	100	100	100	100
R1BE	980	-	-	-	100	100		800	800	800	800	800	800	800	200	100	100	800	800	800	800
R1B(1)E	980	-	-	-	100	100	800		800	800	800	800	800	800	200	100	100	800	800	800	800
R1DE	1,050	-	-	-	100	100	800	800		800	800	800	800	800	200	100	100	800	800	800	800
R2C(1)E	2,000	-	-	-	100	100	800	800	800		1,700	1,700	1,700	1,700	100	200	100	800	800	800	1,700
R3AE	2,000	-	-	-	100	100	800	800	800	1,700		1,700	1,700	1,700	100	100	200	800	800	800	1,700
R3BE	2,000	-	-	-	100	100	800	800	800	1,700	1,700		1,700	1,700	100	100	200	800	800	800	1,700
R3CE	2,000	-	-	-	100	100	800	800	800	1,700	1,700	1,700		1,700	100	200	100	800	800	800	1,700
R3DE	2,000	-	-	-	100	100	800	800	800	1,700	1,700	1,700	1,700		100	100	200	800	800	800	1,700
ROAB	200	-	-	-	200	200	200	200	200	100	100	100	100	100		100	100	100	100	100	100
ROBB	200	-	-	-	100	100	100	100	100	200	100	100	200	100	100		100	100	100	100	100
ROCB	200	-	-	-	100	100	100	100	100	100	200	200	100	200	100	100		100	100	100	100
R1AB	1,100	-	-	-	100	100	800	980	800	800	800	800	800	800	100	100	100		800	800	800
R1BB	1,170	-	-	-	100	100	800	800	800	800	800	800	800	800	100	100	100	800		800	800
R1CB	1,500	-	-	-	100	100	800	800	800	800	800	800	800	800	100	100	100	800	800		800
R2BB	2,300	-	-	-	100	100	800	800	800	2,000	1,700	1,700	2,000	1,700	100	100	100	800	800	800	

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TABLE E-18

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Remote Control GSE
Devel. & Support Equipment

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	4,370		-	4,200	-	-	-	3,500	3,500	3,500	3,500	3,500	3,500	3,500	-	-	-	3,500	3,500	-	3,500
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	4,400	4,200	-		-	-	-	3,500	3,500	3,500	3,500	3,500	3,500	3,500	-	-	-	3,500	3,500	-	3,500
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1B(1)E	4,850	3,000	-	3,000	-	-	-		4,000	3,500	3,500	3,500	3,500	3,500	-	-	-	4,850	4,000	-	4,000
R1DE	7,500	3,000	-	3,000	-	-	-	4,000		6,000	6,000	6,000	6,000	6,000	-	-	-	4,000	7,300	-	6,000
R2C(1)E	8,500	3,000	-	3,000	-	-	-	4,000	6,000		8,100	8,100	8,100	8,100	-	-	-	4,000	4,000	-	8,100
R3AE	8,600	3,000	-	3,000	-	-	-	4,000	6,000	8,100		8,100	8,100	8,100	-	-	-	4,000	4,000	-	8,100
R3BE	8,600	3,000	-	3,000	-	-	-	4,000	6,000	8,100	8,100		8,100	8,100	-	-	-	4,000	4,000	-	8,100
R3CE	8,500	3,000	-	3,000	-	-	-	4,000	6,000	8,100	8,100	8,100		8,100	-	-	-	4,000	4,000	-	8,100
R3DE	8,600	3,000	-	3,000	-	-	-	4,000	6,000	8,100	8,100	8,100	8,100		-	-	-	4,000	4,000	-	8,100
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	4,850	3,000	-	3,000	-	-	-	4,850	4,000	3,500	3,500	3,500	3,500	3,500	-	-	-		4,000	-	4,000
R1BB	1,500	3,000	-	3,000	-	-	-	4,000	7,500	4,000	6,000	6,000	6,000	6,000	-	-	-	4,000		-	4,000
R1CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	8,500	3,000	-	3,000	-	-	-	4,000	6,000	8,300	8,100	8,100	8,300	8,100	-	-	-	4,000	4,000	-	

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TABLE E-19

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

EARTH GSE DEVELOPMENT AND DELIVERED GSE

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	480		480	480	385	385	385	385	385	385	385	385	385	385
F-1-B	480	480		480	385	385	385	385	385	385	385	385	385	385
F-1-C	899	360	360		678	678	678	678	678	678	678	678	678	678
F-2-A	1180	360	360	757		1180	1180	1180	1180	970	970	970	970	970
F-2-B	1180	360	360	757	1180		1180	1180	1180	970	970	970	970	970
F-2-C	1180	360	360	757	1180	1180		1180	1180	970	970	970	970	970
F-2-D	1180	360	360	757	1180	1180	1180		1180	970	970	970	970	970
F-2-E	1180	360	360	757	1180	1180	1180	1180		970	970	970	970	970
F-3-A	1250	360	360	757	970	970	970	970	970		1250	1250	1250	1250
F-3-B	1250	360	360	757	970	970	970	970	970	1250		1250	1250	1250
F-3-C	1250	360	360	757	970	970	970	970	970	1250	1250		1250	1250
F-3-D	1250	360	360	757	970	970	970	970	970	1250	1250	1250		1250
F-3-E	1250	360	360	757	970	970	970	970	970	1250	1250	1250	1250	

TABLE E-19 (CONT.)

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT GSE Development (excluding Remote Control GSE)

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	7,540		800	6,000	800	800	800	3,000	3,000	3,000	3,000	3,000	3,000	3,000	800	800	800	3,000	3,000	2,000	3,000
ROBE	1,500	800		500	1,400	1,400	800	800	800	800	800	800	800	800	500	500	500	800	500	500	800
ROCE	7,500	7,000	500		800	800	800	3,000	3,000	3,000	3,000	3,000	3,000	3,000	800	800	800	3,000	3,000	2,000	3,000
R1AE	2,200	800	1,000	800		2,000	1,800	1,800	1,800	800	800	800	800	800	800	800	800	1,800	1,800	800	800
R1A(1)E	2,650	800	1,000	800	2,500		1,800	1,800	1,800	800	800	800	800	800	800	800	800	1,800	1,800	800	800
R1BE	2,790	800	500	800	2,000	2,000		2,500	2,500	1,000	1,000	1,000	1,000	1,000	1,500	1,500	1,500	2,500	2,500	2,500	1,000
R1B(1)E	8,670	3,000	500	3,000	1,800	1,800	2,500		8,000	5,000	5,000	5,000	5,000	5,000	1,500	1,500	1,500	8,600	8,000	2,500	5,000
R1DE	8,900	3,000	500	3,000	1,800	1,800	2,500	6,000		7,000	7,000	7,000	7,000	7,000	1,500	1,500	1,500	6,000	8,000	2,500	7,000
R2C(1)E	9,210	3,000	500	3,000	800	800	1,800	5,000	7,000		8,800	8,800	9,000	8,800	800	1,700	1,500	5,000	7,000	2,000	8,800
R3AE	9,600	3,000	500	3,000	800	800	1,800	5,000	7,000	8,000		9,200	8,000	9,200	800	1,500	1,700	5,000	7,000	2,000	8,000
R3BE	9,600	3,000	500	3,000	800	800	1,800	5,000	7,000	8,000	9,200		8,000	9,200	800	1,500	1,700	5,000	7,000	2,000	8,000
R3CE	9,210	3,000	500	3,000	800	800	1,800	5,000	7,000	9,000	8,800	8,800		8,800	800	1,700	1,500	5,000	7,000	2,000	9,000
R3DE	9,600	3,000	500	3,000	800	800	1,800	5,000	7,000	8,000	9,200	9,200	8,000		800	1,700	1,700	5,000	7,000	2,000	8,000
ROAB	1,600	800	500	800	800	800	1,500	1,500	1,500	800	800	800	800	800		1,000	1,000	1,500	2,000	1,400	800
ROBB	1,800	800	500	800	800	800	1,500	1,500	1,500	1,700	1,500	1,500	1,700	1,700	1,000		1,000	1,500	1,000	1,400	1,700
ROCB	1,800	800	500	800	800	800	1,500	1,500	1,500	1,500	1,700	1,700	1,500	1,700	1,000	1,000		1,500	1,000	1,400	1,500
R1AB	9,000	3,000	500	3,000	1,800	1,800	2,500	8,650	8,000	5,000	5,000	5,000	5,000	5,000	1,500	1,500	1,500		8,000	2,500	5,000
R1BB	9,100	3,000	500	3,000	2,000	2,000	2,500	8,000	8,900	7,000	7,000	7,000	7,000	7,000	2,000	1,000	1,000	8,000		2,500	7,000
R1CB	5,000	2,000	500	2,000	800	800	2,500	2,500	2,500	2,000	2,000	2,000	2,000	2,000	1,400	1,400	1,400	2,500	2,500		2,000
R2BB	9,450	3,000	500	3,000	800	800	1,800	5,000	7,000	9,050	9,050	9,050	9,050	9,050	800	1,700	1,500	5,000	7,000	2,500	

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TABLE E-20

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Delivered GSE

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	4,560		200	4,000	100	100	100	2,000	2,000	2,000	2,000	2,000	2,000	2,000	100	100	100	2,000	3,000	2,000	3,000
ROBE	550	200		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
ROCE	6,000	5,500	100		100	200	100	2,000	2,000	2,000	2,000	2,000	2,000	2,000	100	100	100	2,000	2,000	200	2,000
R1AE	900	200	100	200		800	700	700	100	100	100	100	100	100	100	100	100	700	700	300	100
R1A(1)E	1,100	200	100	200	800		700	700	100	100	100	100	100	100	100	100	100	700	700	300	100
R1BE	1,100	300	100	200	700	700		1,100	1,100	200	200	200	200	200	100	100	100	1,000	1,000	1,000	700
R1B(1)E	6,700	2,700	100	4,000	700	700	1,100		6,000	2,000	2,000	2,000	2,000	2,000	100	100	100	6,500	6,000	2,000	3,000
R1DE	12,000	3,000	100	2,000	700	700	1,100	6,000		9,000	9,000	9,000	9,000	9,000	100	100	100	6,000	12,000	2,000	9,000
R2C(1)E	17,100	3,000	100	2,000	100	100	700	3,000	7,000		16,000	16,000	17,000	16,000	100	100	100	3,000	9,000	200	17,000
R3AE	17,400	3,000	100	2,000	100	100	700	3,000	7,000	16,000		17,000	16,000	17,100	100	100	100	3,000	9,000	200	16,000
R3BE	17,400	3,000	100	2,000	100	100	700	3,000	7,000	16,000	17,100		16,000	17,100	100	100	100	3,000	9,000	200	16,000
R3CE	17,100	3,000	100	2,000	100	100	700	3,000	7,000	17,000	16,000	16,000		16,000	100	100	100	3,000	9,000	200	17,000
R3DE	17,400	3,000	100	2,000	100	100	700	3,000	7,000	16,000	17,100	17,100	16,000		100	100	100	3,000	400	200	16,000
ROAB	500	250	100	100	100	100	400	400	400	100	100	100	100	100		400	400	400	100	200	100
ROBB	550	250	100	100	100	100	200	200	200	450	300	300	450	300	400		450	200	100	200	450
ROCB	550	250	100	100	100	100	200	200	200	300	450	450	300	450	400	450		200	100	200	400
R1AB	7,000	2,700	100	4,000	700	700	1,100	6,750	1,100	2,000	2,000	2,000	2,000	2,000	100	100	100		6,000	2,000	3,000
R1BB	12,300	3,000	100	2,000	700	700	1,000	6,000	12,000	9,000	9,000	9,000	9,000	9,000	400	100	100	6,000		1,000	9,000
R1CB	3,500	2,000	100	200	300	300	1,000	2,000	2,000	200	200	200	200	200	200	200	200	2,000	1,000		200
R2BB	17,300	3,000	100	2,000	100	100	700	3,000	7,000	17,000	16,000	16,000	17,000	17,000	100	400	400	3,000	9,000	200	

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TABLE E-21

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

TRAINING AIDS AND SUPPORT EQUIPMENT

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	G-3-C	F-3-D	F-3-E
F-1-A	879		439	439	-	-	-	-	-	-	-	-	-	-
F-1-B	930	465		465	-	-	-	-	-	-	-	-	-	-
F-1-C	1279	639	639		-	-	-	-	-	-	-	-	-	-
F-2-A	1720	-	-	-		860	860	860	-	860	860	860	860	-
F-2-B	1947	-	-	-	973		973	973	-	973	973	973	973	-
F-2-C	2235	-	-	-	1118	1118		1118	-	1118	1118	1118	1118	-
F-2-D	2294	-	-	-	1147	1147	1147		-	1147	1147	1147	1147	-
F-2-E	2738	-	-	-	-	-	-	-		-	-	-	-	1364
F-3-A	1973	-	-	-	986	986	986	986	-		986	986	986	-
F-3-B	2496	-	-	-	1248	1248	1248	1248	-	1248		1248	1248	-
F-3-C	2751	-	-	-	1375	1375	1375	1375	-	1375	1375		1375	-
F-3-D	3321	-	-	-	1660	1660	1660	1660	-	1660	1660	1660		-
F-3-E	2792	-	-	-	-	-	-	-	1396	-	-	-	-	

TABLE E-21 (CONT.)

PRIOR DEVELOPMENT SAVINGS MATRIX

(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Training Aids & Support Equipment

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED: NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	990	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	200	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	1,000	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	500	-	-	-	X	350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	500	-	-	-	300	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	850	-	-	-	-	-	X	800	-	-	-	-	-	-	-	-	-	700	700	-	-
R1B(1)E	860	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	700	-	-
R1DE	860	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	700	-	-
R2C(1)E	2,230	-	-	-	-	-	-	-	-	X	-	-	500	-	-	-	-	-	-	-	2,000
R3AE	2,300	-	-	-	-	-	-	-	-	-	X	2,000	-	2,000	-	-	-	-	-	-	-
R3BE	2,300	-	-	-	-	-	-	-	-	-	2,000	X	-	2,000	-	-	-	-	-	-	-
R3CE	2,230	-	-	-	-	-	-	-	-	2,000	-	-	X	-	-	-	-	-	-	-	2,000
R3DE	2,300	-	-	-	-	-	-	-	-	-	2,000	2,000	-	X	-	-	-	-	-	-	-
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
R1AB	1,000	-	-	-	-	-	700	700	700	-	-	-	-	-	-	-	-	X	700	-	-
R1BB	1,000	-	-	-	-	-	-	-	700	-	-	-	-	-	-	-	-	-	X	-	-
R1CB	1,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
R2BB	2,300	-	-	-	-	-	-	-	-	2,000	-	-	2,000	-	-	-	-	-	-	-	X

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TABLE E-22

DESIGN POINT LUNAR FLYING VEHICLES

PRIOR DEVELOPMENT SAVINGS MATRIX

USE OF GOVERNMENT FACILITIES

(Thousands of Dollars)

← Prior Vehicle Developed →

Concept to be Developed	No Prior Development	F-1-A	F-1-B	F-1-C	F-2-A	F-2-B	F-2-C	F-2-D	F-2-E	F-3-A	F-3-B	F-3-C	F-3-D	F-3-E
F-1-A	270		-	-	-	-	-	-	-	-	-	-	-	-
F-1-B	270	-		-	-	-	-	-	-	-	-	-	-	-
F-1-C	270	-	-		-	-	-	-	-	-	-	-	-	-
F-2-A	541	-	-	-		-	-	-	-	-	-	-	-	-
F-2-B	541	-	-	-	-		-	-	-	-	-	-	-	-
F-2-C	541	-	-	-	-	-		-	-	-	-	-	-	-
F-2-D	541	-	-	-	-	-	-		-	-	-	-	-	-
F-2-E	1100	-	-	-	-	-	-	-		-	-	-	-	-
F-3-A	541	-	-	-	-	-	-	-	-		-	-	-	-
F-3-B	541	-	-	-	-	-	-	-	-	-		-	-	-
F-3-C	541	-	-	-	-	-	-	-	-	-	-		-	-
F-3-D	541	-	-	-	-	-	-	-	-	-	-	-		-
F-3-E	1100	-	-	-	-	-	-	-	-	-	-	-	-	

TABLE E-22 (CONT.)

PRIOR DEVELOPMENT SAVINGS MATRIX
(thousands of dollars)

PROGRAM DEVELOPMENT ELEMENT Use of Gov't Facilities

CONCEPT TO BE DEVELOPED	PRIOR VEHICLE DEVELOPED																				
	NO PRIOR DEVEL.	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
ROAE	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROBE	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ROCE	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1AE	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1A(1)E	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1BE	4,350	-	-	-	-	-		4,350	-	-	-	-	-	-	-	-	-	4,350	-	-	-
R1B(1)E	4,350	-	-	-	-	-	4,350		-	-	-	-	-	-	-	-	-	4,350	-	-	-
R1DE	4,350	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	4,350	-	-
R2C(1)E	7,600	-	-	-	-	-	-	-	-		-	-	7,600	-	-	-	-	-	-	-	7,600
R3AE	7,600	-	-	-	-	-	-	-	-	-		7,600	-	2,400	-	-	-	-	-	-	-
R3BE	8,700	-	-	-	-	-	-	-	-	-	7,600		-	2,400	-	-	-	-	-	-	-
R3CE	7,600	-	-	-	-	-	-	-	-	7,600	-	-		-	-	-	-	-	-	-	7,600
R3DE	10,000	-	-	-	-	-	-	-	-	-	6,000	6,000	-		-	-	-	-	-	-	-
ROAB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
ROBB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
ROCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
R1AB	4,350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
R1BB	4,350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
R1CB	4,350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
R2BB	7,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

960-8

E. 4 PRIOR DEVELOPMENT SCHEDULE MATRIX ($\bar{t}_o$)

This matrix (Table E-23) gives the adjusted development schedule when prior vehicles have been developed. Rather than using the nominal schedule t_o of Table E-1 when prior vehicles have been developed, it is assumed that the nominal schedule will be shortened by reason of these prior developments. Therefore, the schedule shown in Table E-23 is read for each prior vehicle developed and the shortest schedule (smallest $\bar{t}_o$) is used in place of t_o.

E. 5 m vs Q_0

During the costing process, a quantity Q_0 is computed as the ratio of the desired schedule to the nominal development schedule. If the desired schedule is much shorter than nominal, the development cost will be

TABLE E-23

PRIOR DEVELOPMENT SCHEDULE MATRIX
(HALF-YEARS)

			PRIOR VEHICLE DEVELOPED																		
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
		Vehicle Number	ROAE	ROBE	ROCE	R1AE	R1A(1)E	R1BE	R1B(1)E	R1DE	R2C(1)E	R3AE	R3BE	R3CE	R3DE	ROAB	ROBB	ROCB	R1AB	R1BB	R1CB	R2BB
CONCEPT TO BE DEVELOPED	ROAE	14		5.00	4.67	5.00	5.00	5.00	5.00	5.00	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.17	5.17	5.17	5.33
	ROBE	15	4.67		4.67	4.67	4.67	4.67	4.67	4.67	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.67	4.67	4.67	5.00
	ROCE	16	5.00	5.33		5.33	5.33	5.33	5.33	5.33	5.50	5.50	5.50	5.50	5.50	5.67	5.67	5.67	5.33	5.33	5.33	5.50
	R1AE	17	5.17	5.17	5.17		4.67	5.17	5.17	5.17	5.33	5.33	5.33	5.33	5.33	5.17	5.50	5.50	5.17	5.17	5.17	5.33
	R1A(1)E	18	5.17	5.17	5.17	5.17		5.17	5.17	5.17	5.33	5.33	5.33	5.33	5.33	5.17	5.50	5.50	5.17	5.17	5.17	5.33
	R1BE	19	5.33	5.33	5.00	5.17	5.17		5.00	5.00	5.33	5.33	5.33	5.33	5.33	5.17	5.50	5.50	5.00	5.00	5.00	5.33
	R1B(1)E	20	5.67	5.83	5.50	5.83	5.83	5.50		5.50	5.50	5.50	5.50	5.50	5.50	5.67	6.00	6.00	4.00	5.50	5.50	5.50
	R1DE	21	6.33	6.67	6.33	6.33	6.33	6.33	6.33		6.00	6.00	6.00	6.00	6.00	6.67	6.67	6.67	6.33	4.67	6.33	6.00
	R2C(1)E	22	9.00	9.00	8.67	8.67	8.67	8.67	8.67	8.33		8.33	8.33	5.00	8.33	9.00	8.67	9.00	8.67	8.33	8.67	5.00
	R3AE	23	9.33	9.33	9.00	9.00	9.00	9.00	9.00	8.67	8.33		5.00	8.33	6.00	9.33	9.17	9.00	9.00	8.67	9.00	8.33
	R3BE	24	9.67	9.67	9.33	9.33	9.33	9.33	9.33	9.00	8.67	5.00		8.67	6.00	9.67	9.50	9.33	9.33	9.00	9.33	8.67
	R3CE	25	9.33	9.33	9.00	9.00	9.00	9.00	9.00	8.67	5.00	8.33	8.33		8.33	9.33	9.00	9.33	9.00	8.67	9.00	5.00
	R3DE	26	9.67	9.67	9.33	9.33	9.33	9.33	9.33	9.33	8.67	6.00	6.00	8.67		9.67	9.67	9.33	9.33	9.33	9.33	9.33
	ROAB	27	4.67	4.67	4.67	4.67	4.67	3.00	3.00	3.00	4.67	4.67	4.67	4.67	4.67		4.67	4.67	3.00	3.00	3.33	4.67
	ROBB	28	5.00	5.00	4.67	4.50	4.50	4.50	4.50	4.50	3.00	4.00	4.00	3.00	4.00	4.67		4.67	4.50	4.50	4.50	3.00
	ROCB	29	5.00	5.00	5.00	4.83	4.83	4.83	4.83	4.83	4.00	3.00	3.00	4.00	3.00	5.00	5.00		4.83	4.83	4.83	4.00
	R1AB	30	5.50	5.50	5.50	5.00	5.00	5.00	5.00	5.00	5.33	5.50	5.50	5.33	5.50	5.33	5.50	5.50		5.00	5.00	5.33
	R1BB	31	6.67	6.67	6.67	6.67	6.67	6.67	6.67	4.83	6.00	6.00	6.00	6.00	6.00	6.67	6.67	6.67	6.67		6.67	6.00
	R1CB	32	6.33	6.33	6.33	6.00	6.00	6.00	6.00	6.00	6.00	6.33	6.33	6.00	6.33	6.17	6.33	6.33	6.00	6.00		6.00
	R2BB	33	9.00	9.00	9.00	9.00	9.00	9.00	9.00	8.33	5.50	8.00	8.00	6.33	8.00	9.00	8.83	9.00	9.00	8.33	9.00	

increased until at some point (assumed to be at a ratio of 0.8) the shortened schedule cannot be met. If the desired schedule is significantly greater than the nominal, costs will also rise due to the stretchout. A function to represent these trends was developed and is plotted in Figure E-1. The analytical expression used in the computer is shown below.

If $Q_0 < 1.0$ then $m = 1.0 - 1.5\,(Q_0 - 1.0)$

If $1.0 \leq Q_0 \leq 1.1$ then $m = 1.0$

If $1.1 < Q_0$ then $m = 1.0 + 0.7\,(Q_0 - 1.1)$

E.6 COST SPREADING

The total costs as developed in schedule/total cost may be spread by half years over the development schedule during the cost spreading subroutine. Both committed and expended funds are computed. The spreading is based on the trends shown in Figure E-2, the development of which is discussed in Volume II, Book 5. From Figure E-2, the fraction of the total cost to be allotted to each half year of the development schedule can be determined. These allocations are shown in Table E-24 according to the quantity M which is the number of half years in the adjusted development schedule.

Committed funds allocations are shown under Z and expended are shown under X.

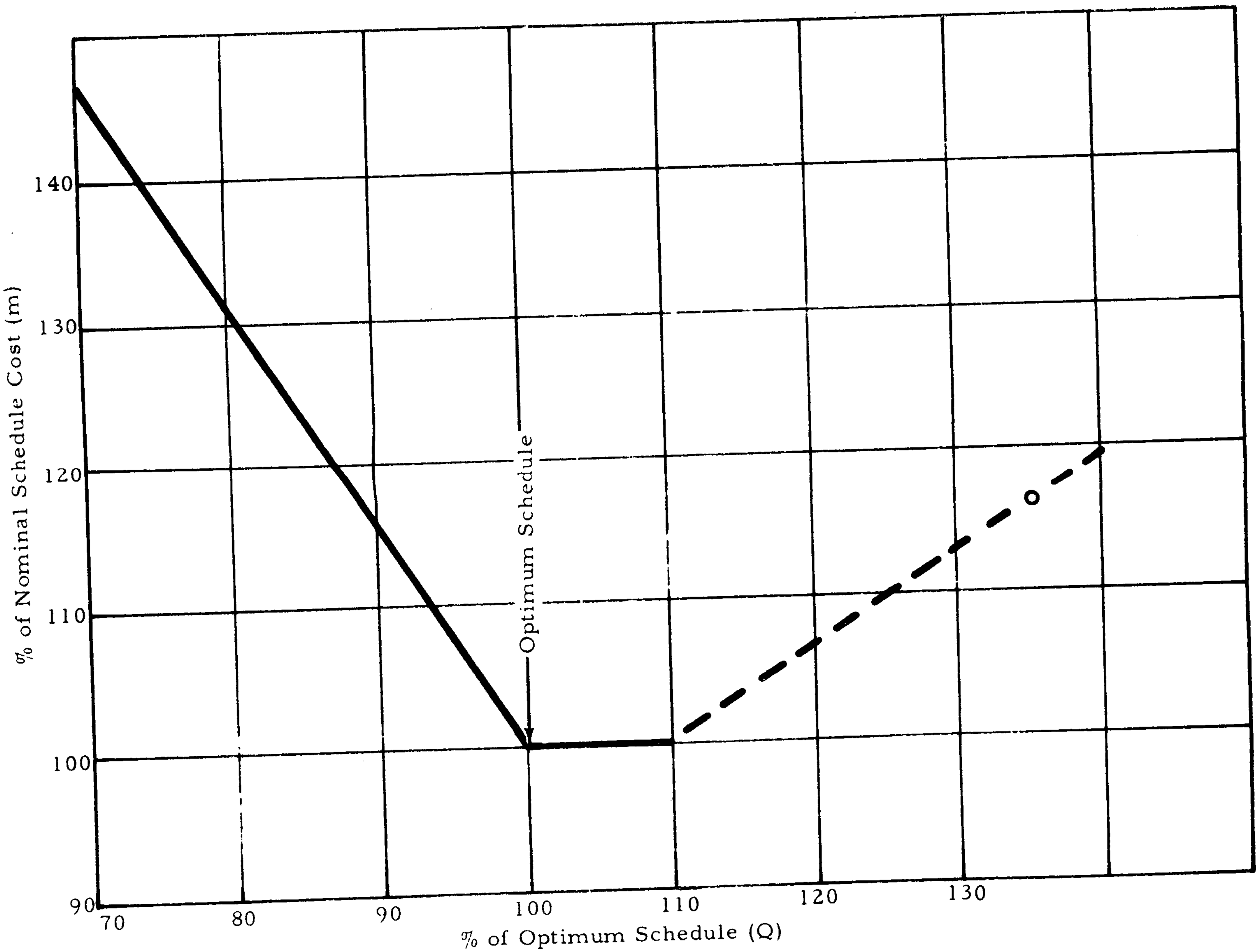

Figure E-1 Effect of Schedule Variation on Cost

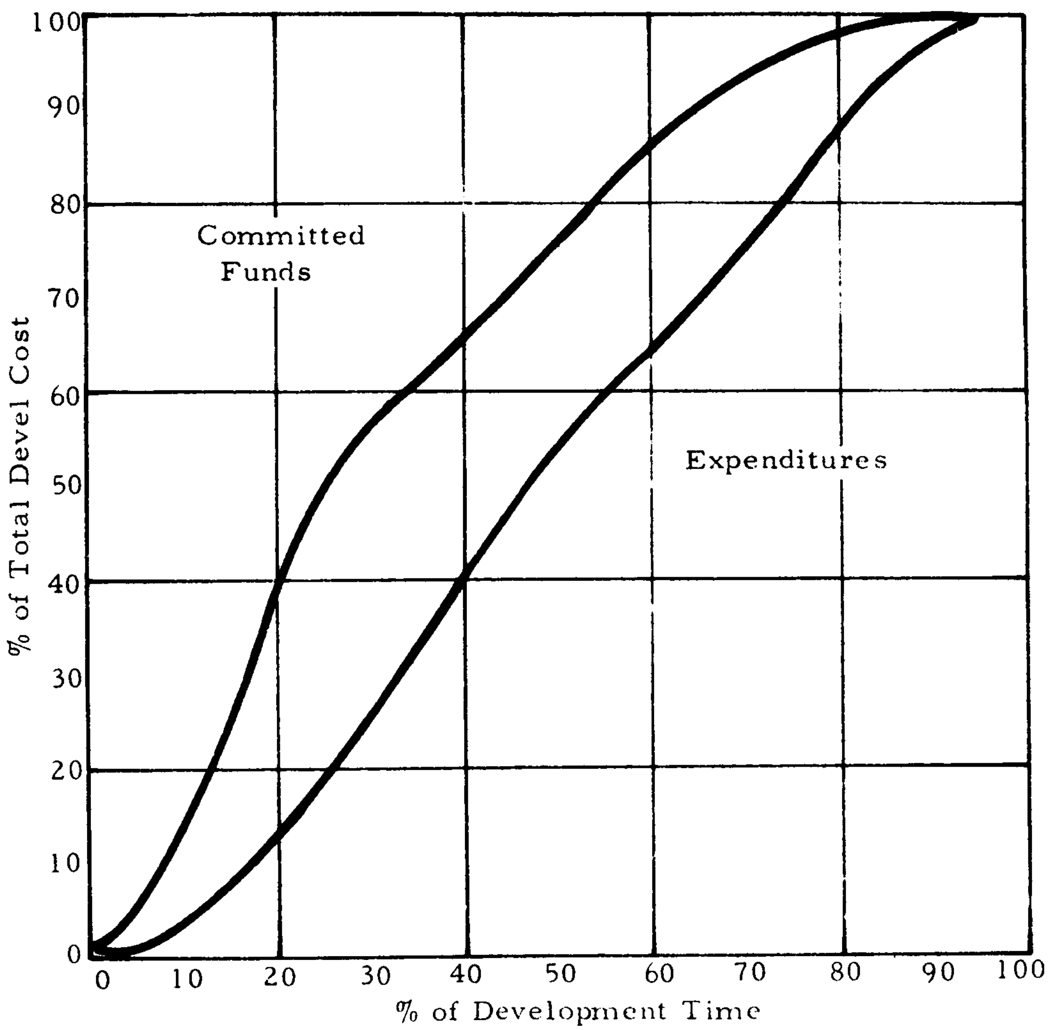

Figure E-2 Lunar Vehicle Committed Funds Versus Actual Expenditures

TABLE E-24

SPREADING ALLOCATIONS

Fraction Allocated Per Half-Year

M		1	2	3	4	5	6	7	8	9	10	11	12
2	z	0.757	0.243										
	x	0.540	0.460										
3	z	0.595	0.312	0.93									
	x	0.300	0.410	0.290									
4	z	0.500	0.255	0.205	0.040								
	x	0.183	0.357	0.270	0.190								
5	z	0.385	0.275	0.194	0.128	0.018							
	x	0.125	0.275	0.240	0.230	0.130							
6	z	0.307	0.290	0.158	0.150	0.085	0.010						
	x	0.090	0.210	0.240	0.170	0.200	0.090						
7	z	0.245	0.305	0.137	0.138	0.115	0.056	0.004					
	x	0.070	0.160	0.214	0.167	0.153	0.173	0.063					
8	z	0.200	0.300	0.135	0.120	0.120	0.085	0.040	0.000				
	x	0.053	0.130	0.176	0.181	0.125	0.145	0.140	0.050				
9	z	0.170	0.270	0.156	0.105	0.107	0.097	0.069	0.026	0.000			
	x	0.044	0.106	0.147	0.167	0.129	0.115	0.132	0.121	0.039			
10	z	0.150	0.240	0.175	0.095	0.095	0.095	0.080	0.052	0.018	0.000		
	x	0.036	0.089	0.125	0.150	0.140	0.100	0.105	0.125	0.100	0.030		
11	z	0.132	0.216	0.186	0.090	0.087	0.089	0.086	0.062	0.040	0.012	0.000	
	x	0.031	0.074	0.109	0.128	0.138	0.101	0.095	0.102	0.113	0.087	0.022	
12	z	0.114	0.101	0.195	0.098	0.075	0.082	0.082	0.069	0.054	0.030	0.010	0.000
	x	0.028	0.062	0.093	0.115	0.127	0.115	0.082	0.088	0.098	0.102	0.070	0.020